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Local-Rapid Evaluation of Atmospheric Conditions (L-REAC®) System, Design and Development Volume 5 (Mobile L-REAC® System "Proof of Concept" and Four Feasibility Studies)

by Gail Vaucher

ARL-TR-6275   **December 2012**

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Army Research Laboratory

White Sands Missile Range, NM 88002-5501

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Computational and Information Sciences Directorate, ARL

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14. ABSTRACT The U.S. Army Research Laboratory (ARL) has been designing and developing a decision aid called the *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC®) System.* Please note that the L-REAC® System trademark is owned by the Department of the Army, Washington DC, 20310. This tool is a product of the 2003–2007 Urban Field Studies, which investigated the airflow and stability characterization around a single urban building, and small building clusters. The primary goal for L-REAC® is to improve Soldier/civilian situational awareness of environmental airborne hazards during potentially life-threatening events. L-REAC® accomplishes this goal by mapping a near-real-time wind field and plume (when available) over an area of interest. *L-REAC® System, Volume 1* presented the L-REAC® "Proof of Concept" System. *L-REAC® System, Volume 2* described the L-REAC® Prototype. *L-REAC® System, Volume 3* described the Operational L-REAC® System, which continues to be used in real world events. *L-REAC® System, Volume 4* summarized detailed L-REAC® System feedback given by professional and volunteer emergency first responders. In this *Volume (#5)*, the Mobile L-REAC® "Proof of Concept" System, four forward-looking Feasibility Studies and a brief L-REAC® Project résumé are documented.					
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Executive Summary

This report documents the design and construction of a *Mobile* Local-Rapid Evaluation of Atmospheric Conditions (L-REAC®)* System "*Proof of Concept,*" (*PoC*) as well as four feasibility studies, each representing starting thresholds for a wide variety of potential L-REAC® Project growth.

The L-REAC® System concept was a product of the 2003–2007 White Sands Missile Range (WSMR) Urban Field Studies, which investigated the airflow and stability characterization around a single urban building and small building clusters. The primary goal for L-REAC® is to improve Soldier/civilian situational awareness of environmental airborne hazards during potentially life-threatening events. L-REAC® accomplishes this goal by mapping a near-real-time wind field and plume (when available) over an area of interest (AOI). From 2009 to 2012, the initial viewgraph technology has evolved into a "PoC" System (2009), a Prototype (2010), an Operational L-REAC® System (2011) and now, a Mobile L-REAC® System "PoC" (2012).

The Mobile L-REAC® System "PoC" design and construction was subdivided into two parts: mobilizing the L-REAC® System platform and mobilizing the L-REAC® System Modules. The transportable platform selected for the "PoC" unit was a DELL M6500 Laptop (64-bit, Vista). While constructing the System, efficiency enhancements were woven into the new design. For example, the Mobile L-REAC® System reduced the operating system (OS) requirements from two (Windows and UNIX) to one (Windows only). The directory structure on the Mobile unit was reduced by one complete layer, bringing the system code one step closer to a DVD installation format. The System *Start-up* routine was re-structured, resulting in a two program startup procedure that included more user options. These options were divided into three categories: Model Resolution (building scale-5 m, cantonment scale-50 m, or regional scale-100 m), Output Location(s) (Demilitarized Zone [DMZ] network, website and/or local computer) and a binary Image Archive option. Finally, the System *Shutdown* procedure was reduced to a single, user-friendly step.

Mobilizing the modules began with the Sensor Module. The first stand-alone Mobile L-REAC® System utilized a Fixed Sensor Suite (FSS) for the dedicated sensor package. Due to fiscal limitations, the Mobile Sensor Suite (MSS) option had to be temporarily suspended. Fortunately, the opportunity to revisit this MSS design came soon after the Mobile L-REAC® System platform was completed; and, will be described with the feasibility studies.

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* The L-REAC® System trademark is owned by the Department of the Army, Washington DC, 20310.

Mobilizing the Quality Control (QC) and Archive Modules required re-designing their outputs to accommodate both the FSS and MSS (a feasibility study) data formats.

Mobilizing the Model Module was initially defined as being able to apply the models at any location within the Continental United States (CONUS). This feature was already in place for the selected Plume model—Aerial Locations of Hazardous Atmospheres (ALOHA). The selected wind model—Three-Dimensional Wind Field (3DWF) was able to move to new locations; however, the method for setting up the terrain and building databases was not yet "user-friendly." When the L-REAC® wind model colleague retired, this task was re-defined as moving the L-REAC® System to "new" locations within the given AOI. Proposals for building a user-friendly, CONUS-portable 3DWF were written, but not funded.

To mobilize the End User Display (EUD) Module, a "local" end user display option was added to the Mobile L-REAC® System design. This "local" option allowed the System to function as a "stand-alone" unit in a field situation. This attribute also enabled System testing without impacting the primary L-REAC® System output, which was concurrently being used operationally, 24-h a day/7-days a week (24/7).

The option to send L-REAC® System output to a government-managed website was also added, as a result of a concurrently executed, feasibility study. Both the Operational and Mobile L-REAC® Systems benefited from the Study's success, which will be elaborated on later. Finally, both Operational and Mobile EUD Modules received a cosmetic update, "®", to accommodate the recently registered L-REAC® trademark.

The four feasibility studies completed in Fiscal Year 2012 (FY12) included:

- Expanding the L-REAC® output options to include a website,

- Integrating the L-REAC® output into a System of Systems (SoS),

- Augmenting the dedicated L-REAC® sensor choices to include a MSS, and

- Simulating a multi-processor L-REAC® System design.

Each study represented a launch point for a wide variety of potential L-REAC® Project growth and is summarized in the following:

1. The website feasibility study was a collaboration between U.S. Army Research Laboratory (ARL) and the WSMR Information Management Division (IMD) webmaster. The EUD was re-formatted for an Army-compliant web page, supported by the White Sands Data Management (WSDM). Once the website was successfully tested, this capability became an active service for both the Operational and Mobile L-REAC® Systems. As a result, L-REAC® now has the potential for communicating with a much wider (CONUS and Overseas) and diversified Army

and Civilian community. There is also the opportunity for adding user-friendly, handheld communication device formats.

2. Integrating the L-REAC® output into a SoS was a product of an ARL and Fort Bliss, TX, collaboration. Automated L-REAC® output was successfully transmitted to an Installation Management System (IMS) laptop, provided by the Fort Bliss-Directorate of Plans, Training, Mobilization and Security (DPTMS). To further demonstrate the L-REAC® capabilities, L-REAC® output was also brought into the SoS JPM Guardian software "Consequence Management Tool Set-Version 6" (CATS6), as a layer of information on the mapped CATS6 engineering diagram output. The proprietary nature of the CATS6 prohibited automating this integration action. The success of this feasibility study demonstrates the L-REAC® ability to enrich larger SoS products with timely and relevant local scale information.

3. The ideal Mobile L-REAC® System includes a MSS as the "dedicated sensor." Collaborating with Coastal Environmental Systems, Inc. (CES), this ideal became a reality. The CES WEATHERPAK®† Multiple Threat Response (MTR) sensor suite was designed for hazardous material (HAZMAT) environments. Not only is this meteorological resource wireless, but it is designed to be assembled and used by HAZMAT-suited first responders. The Mobile L-REAC® System adapted the Sensor, QC and Archive modules to accommodate the WEATHERPAK MTR data format, after which this MSS technology was successfully demonstrated as part of the Mobile L-REAC® System. The potential opportunities gleaned from the MSS are better seen when coupled with the final feasibility study.

4. A multi-processor L-REAC® System design was part of the initial vision for the L-REAC® System. The blueprint concept was labeled the L-REAC® System "Core and 2nd Tier" design. The "core" was envisioned as an L-REAC® System running 24/7, producing output over a given AOI every 2–10 min (depending on the wind/plume model resolution selected). The "2nd Tier" was visualized as an independent, computer platform running a slower, application-relevant model (or models). The end products of the two resources would be delivered to the end user, as they became available.

   For this Feasibility Study, the "core" system was the Mobile L-REAC® System with the MSS, running a 5 m resolution wind model. The "2nd Tier" was the Operational L-REAC® System with the FSS, running a 100 m resolution wind model. Both systems fed their output to the DMZ display. The users received the "core" output every 1–2 min and the "2nd Tier" output every 8–10 min. In a second test, the wind models were supplemented with plume models running, concurrently.

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† WEATHERPAK is a registered trademark of Coastal Environmental Systems, Inc.

The results of these four model resources were fed to the DMZ display. On a third test, the four model results were successfully communicated through the WSDM website.

The potential gained from the multi-processor study is quite extensive. For example: First responders to airborne hazards could run mobile and operational systems, concurrently. Or, their "2nd Tier" model could be a 1–3-h forecast model. Thus, L-REAC® would answer both the first and second weather-related questions asked by an incident commander: "What are the winds now?" and, "What will they be in 1–3 hrs?" Looking beyond airborne hazards, any application requiring near real-time winds / atmospheric conditions can now be addressed. The automated "core" system would faithfully provide the local, real-time atmospheric conditions, while the "2nd tier" would assimilate these data into slower running application models such as micro-unmanned aerial vehicle (µUAV) flight routing models, nuclear effects models, etc.

Over the past almost five years, the L-REAC® System developers have crossed several milestones beyond their technical achievements, such as a patent submission, the registering of a trademark and various product endorsements. Chapter 4 assimilates some of the major 2008-to-present milestones, through a brief project résumé of accomplishments.

This document is possibly the final L-REAC® System development report. Due to budget cuts, the Battlefield Environment Division (BED) management has decided that any further L-REAC® System development will need a sponsor outside of ARL-BED mission funding. At the time of this writing, the L-REAC® System operational function was in the process of being transferred to a safety-operations organization.

The long term vision of the L-REAC® System has been to bring the L-REAC® System technology to the Army soldier. While the continued development of current L-REAC® technology is pending funding, it is the hope of the author that enough of the system details have been documented, so that when the need and funding come together, the next development effort can bring this technology to its intended goal. That is, the L-REAC® decision aid will continue to make a difference in the mission of saving civilian and Soldier lives.

1. Background

This report describes the design and construction of a *Mobile* Local-Rapid Evaluation of Atmospheric Conditions (L-REAC®)‡ System "*Proof of Concept*," (*PoC*) followed by four significant feasibility studies completed in fiscal year 2012 (FY12). The four studies include:

- Expanding the L-REAC® output options to include a website,

- Integrating the L-REAC® output into a System of Systems (SoS),

- Augmenting the dedicated L-REAC® sensor choices to include a mobile sensor suite (MSS), and

- Simulating a multi-processor L-REAC® System design.

Each study represents a starting threshold for a wide variety of potential L-REAC® Project growth. Consequently, the studies and their impacts will be described in section 3. The report concludes with a brief L-REAC® Project résumé of significant milestones (see appendices A–C for endorsements) and a summary.

The L-REAC® System was developed by the U.S. Army Research Laboratory (ARL), as a decision aid to help protect Soldiers and civilians from airborne hazard threats and releases. The original "PoC" design consisted of ingesting real-time meteorological data, which were used by wind and plume (when toxin inputs were available) models to generate synchronized wind field and plume outputs overlaid onto a common map background; The results were then automatically presented to pre-approved users in near real-time. This modularized tool was not limited to airborne hazard applications, but was designed to apply to any service or function that required a synchronized mapping of near real-time, high resolution atmospheric (wind) data, with an application. Examples of alternate applications include: micro-unmanned air vehicle flight path checks, nuclear effects testing, high energy laser tests, artillery trajectories, etc.

Since the original L-REAC® System demonstration unit was constructed for airborne hazards, the subsequent Mobile L-REAC® System "PoC" demonstration unit utilized the plume model for its application, as well.

To better understand the L-REAC® System decision aid role in a toxic airborne hazard application, consider the following scenario:

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‡ The L-REAC® System trademark is owned by the Department of the Army, Washington DC, 20310.

A tanker truck driving through a business district of an urban community accidentally hits a street light creating a leak in the chemical tank.

There are many types of decisions made during an emergency. For the given incident, a typical sequence of decisions, in chronological order might be:

1. The onsite witnesses standing near the initial accident need to determine where a safe location is, so they can retreat from the potentially life-threatening situation.

2. Building occupants near the incident must decide whether to Shelter-in-Place (SIP), evacuate or take the time to call for help.

3. Building custodians and/or supervisors must decide how to advise building occupants and secure help.

4. Help Dispatch (911) operators must decide how to advise residents (SIP, evacuate). When they dispatch the response units (security, safety and property preservation), they have an opportunity to suggest how these units might safely approach the hazardous incident.

5. Each emergency unit dispatched must determine the critical safety requirements with regard to their approach and their assigned tasks. For example:

    5.1 Professional emergency responders may be assigned responsibilities in or near the airborne hazard. If their special protective gear fails, they will need to be aware of a safe and quick retreat.

    5.2 Security: Police assigned to security and traffic control need to know the hazards of their assigned duty site and task, which may be securing a building, directing traffic, etc.

    5.3 Safety: Medical units need to establish Hazard Control Zones for addressing the incident (hot zone), for detoxifying personnel/equipment (warm zone), and for providing a safe environment in which their multiple support activities can function (cold zone).

    5.4 Property: Fire units need to address current and potential structural hazards in and around the incident area. (Safety and property functions often occur in parallel.)

6. Incident Commanders (at a command center and/or in the field) need to conceptualize the extent of the incident's impact and advise field units accordingly.

All these critical decisions, as well as other cascaded choices, would continue until the area of interest (AOI) is once again declared safe for public use.

How can these decision makers make informed and potentially life-saving decisions? One way is to use the timely and relevant mapped atmospheric and (when available) plume information from the L-REAC® System. For example:

(#1) The civilian and/or military onsite person witnessing the incident can visually inspect the wind monitor dedicated to the L-REAC® System, to determine where "upwind" is, and evaluate whether to head in that direction.

(#2–4) Building occupants, custodians and dispatch persons who have determined to evacuate the area can utilize the near real-time wind field to identify the "upwind" region and assess if this area is the best choice for safety.

(#5) Professionals responding to the incident can reference the current flow fields to determine the hot, warm, and cold zone orientation, as well as the implied atmospheric impacts on their individual responsibilities.

(#6) Finally the Incident Commanders can integrate the mapped air flow into their scenario visualization.

Following a hazardous release incident, environmental remediation occurs. The L-REAC® System archived data and images can assist with this remediation.

The research that prompted the creation of the L-REAC® System is described next, followed by a description of the system.

1.1 Research Leads to New Technology

The concept for the L-REAC® System Project began with an ARL investigation into the airflow and stability around a single urban building. Three progressively more complex urban field studies were conducted in the early 2000s. The initial study, called *White Sands Missile Range (WSMR) 2003 Urban Study* (*W03US),* sought to verify seven airflow features identified around a rectangular office building structure, in a 1994 Environmental Protection Agency (EPA)/National Oceanic and Atmospheric Administration (NOAA) wind tunnel study. Six of the seven features are shown in figure 1: fetch flow, velocity acceleration, velocity deficit, cavity flow, leeside corner eddies/vortices and the re-attachment zone. The seventh feature, a "canyon flow" is an accelerated flow that occurs between two parallel buildings. The successful *W03US* results prompted two subsequent urban studies around the same urban environment, each with an increased density of dynamic and thermodynamic measurements. These studies were called *WSMR 2005 Urban Study (W05US)* and *WSMR 2007 Urban Study (W07US)*, respectively. ARL technical reports documenting these studies and their findings include:

- Urban Study Overview (Vaucher, 2006);

- Data Processing—Vaucher et al., 2008 (*Volumes DP-1, DP-2, DP-3; 2008a, b, and c*);

- Atmospheric Stability Analysis—Vaucher, 2007 (*Volume AS-1; 2007*); Vaucher, 2008 (*Volume AS-2; 2008*);

- Airflow Data Analysis—Vaucher, 2011 (*Volume DA-1; 2011*).

During the final field study, simulated disaster response drills were concurrently executed. The need for a near real-time atmospheric evaluation system was identified as a "lesson learned."
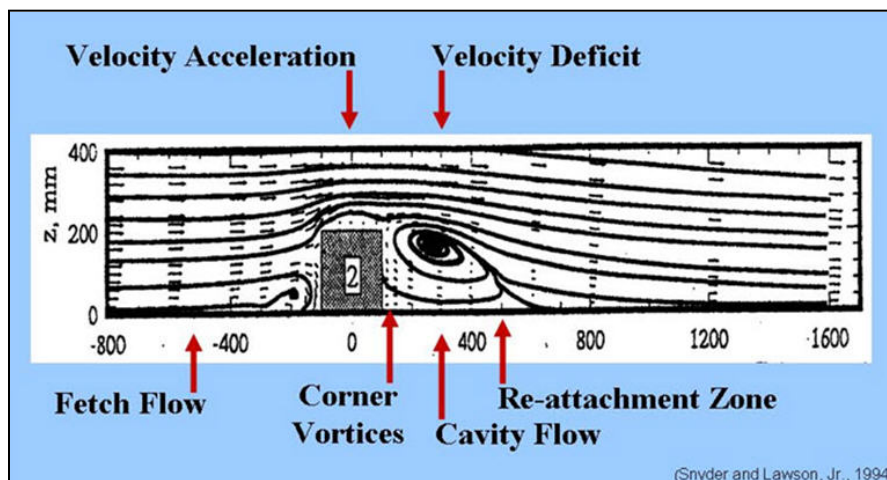
Figure 1. 1994 EPA/NOAA wind tunnel results show the airflow pattern around a single
structure. Streamline flow is from left to right. The "canyon flow" is not shown.
(Snyder and Lawson, Jr., 1994).

In 2009, the first L-REAC® System, a "PoC," was constructed. This near real-time atmospheric evaluation system included a Linux-Windows dual operating system (OS) with three core modules linked by specialized networks. The modules consisted of a Sensor Module, a Model Module, and an End-User-Display (EUD) Module (see figure 2). The L-REAC® System PoC was documented in the *Volume 1* (Vaucher et al., 2009).
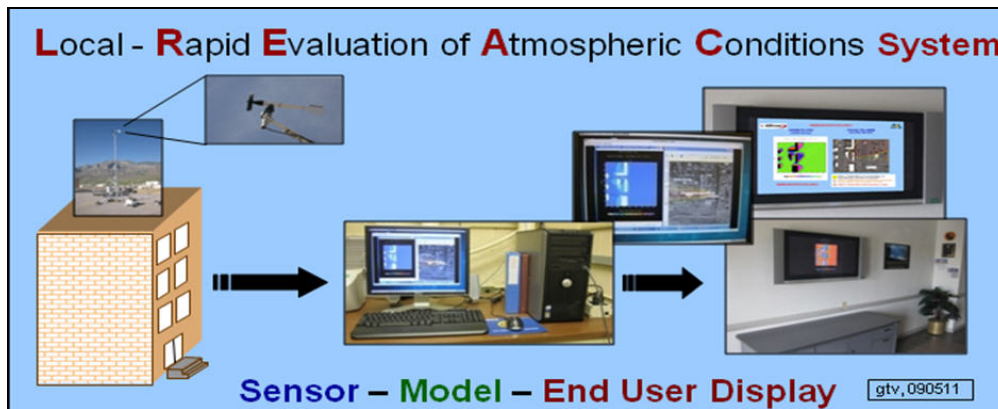
Figure 2. The L-REAC® System PoC included sensors continually acquiring data from a representative location in the AOI, a Wind Field Model continually interpreting the wind flow conditions based on the sensor input, a Plume Model assessing the airborne hazard scenario, and an EUD communicating both the near real-time wind flow and hazard assessments.

In Fiscal Year 2010 (FY10), a single Windows OS L-REAC® System "Prototype" was constructed, with all the Linux functions accommodated through a *cygwin* software package. The three core modules were significantly enhanced, and two former system features, the Quality Control (QC) and Archive, were re-designated as full modules. The "Prototype" System was documented in the *Volume 2* (Vaucher et al., 2010).

In 2011, system module improvements continued, resulting in an Operational L-REAC® System. The increased computational demands required a 32-bit to 64-bit OS conversion. This internal structural change was successfully completed, and impacted all L-REAC® System programs and scripts. The Operational L-REAC® System was documented in the *Volume 3* (Vaucher et al., 2011). This Operational L-REAC® System experienced its first "trial by fire," when it was invited to participate in the April 2011 *Abrams Fire* that threatened to evacuate the entire WSMR Post. Based on the successful *Abrams Fire* experience, the Operational L-REAC® System has remained an active service to the WSMR community, 24-hr a day/7-days a week (24/7), through the writing of this report. An L-REAC® Training program was provided by ARL for the professional and voluntary emergency first response personnel utilizing L-REAC®. The training consisted of five classes, which resulted in two levels of expertise: An L-REAC® User and Operator. As part of the Training II session, ARL gathered user feedback via a 12-page Questionnaire/Evaluation of the Operational L-REAC® System. The results were published in ARL-TR-5848 (Vaucher, 2011).

In FY12, the Operational System continued to service the WSMR community and the L-REAC® development group shifted focus onto system mobility. This report documents the resulting Mobile L-REAC® System, along with the concurrent four feasibility studies completed in FY12.

1.2 The Basic L-REAC® System Design

The basic L-REAC® System design is an automated, 24/7, emergency response decision aid for airborne toxic release incidents. The current L-REAC® System design is composed of five core modules linked by specialized networks. These Modules include a Sensor Module, a QC Module, a Model Module, a EUD Module and an Archive Module. The Sensor Module provides timely (real-time) and relevant atmospheric data from a single and/or an ensemble of meteorological sensors. For example, the design choice of an animated anemometer (wind monitor) within the sensor suite, allows the system to still fulfill the system goal of providing real-time, relevant atmospheric (wind) information, even if an incident is coupled with an area-wide power outage.

The Model Module interprets the contemporary data by generating a local wind field over an AOI. One of three wind field model options (building, cantonment or regional) is selected by the user. The chosen wind field scale is perpetually updated by the Sensor Module data feed and the output is displayed by the EUD Module. When an airborne hazard occurs, a trained operator keys in the hazard specifications (such as the hazard type, amount, release method, etc.) to a quick processing, emergency response plume model. Since model output is highly dependent on the quality of data ingested, a data QC Module allows the user to instantly evaluate the status of all the L-REAC® System sensors.

The EUD Module automatically assimilates and synchronizes the wind and plume model outputs for the end user to utilize for assessing safe/hazard zone decisions. The EUD output is distributed to end users over established networks. Updates to the wind field (and plume) outputs are automatically transmitted to the users after each wind field (plume) model run is completed. A System-specific network ensures a timely information flow (on the order of minutes for the building scales and 8–10 min for the regional scales) from the atmospheric sensors and models, to the decision-maker EUD displays. An "Instantaneous Save" option allows the system operator to zoom in/out on an end-user-specified area and immediately transmit those results, between the automated cycles.

An Archive Module saves the ingested L-REAC® data, and when the user selects the option, this Module saves all incident-EUD imagery, as well. These archive files can be used for incident reviews, Post-Event data analyses and environmental remediation-type tasks.

1.3 Defining a Mobile L-REAC® System

The initial vision for the "mobile" L-REAC® System required adding several capabilities to the Operational L-REAC® System design. First, the System's physical platform (computer) needed to be portable. Second, each module needed to be "mobilized."

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The ideal mobilized system would consist of a laptop L-REAC® System, which could be brought anywhere in the world. The sensor package would need to be easily transported; a user-friendly, wind and plume model re-configuration for alternate locations would be required; and the L-REAC® System output would need to be accessible even without local hardwire network links.

After assessing this vision, the development group determined that the portability of the System platform could be manifested with a laptop computer. As for servicing "the world," this grandiose plan was quickly reduced to "servicing the continental United States," due to terrain and building database access issues.

The transportable sensor package was considered feasible, using commercial-off-the-shelf (COTS) products. Unfortunately, funding was not available to complete this transaction. The portable sensor capability was ultimately successfully completed through a feasibility study, as explained in section 3.3.

The model reconfiguration for alternate locations within the Continental United States (CONUS) was already part of the plume model used by the L-REAC® System demonstration unit. The wind model (an early version), however, was not yet as versatile. Since the L-REAC® System development-group modeler retired just prior to the Mobile L-REAC® System development, proposals to address this task were submitted; none were funded. Consequently, "mobilizing" the L-REAC® System was ultimately re-defined as moving the System within the given wind model AOI footprint.

Accessing the L-REAC® System output through wireless communications could not be approved under the current government security regulations. However, the L-REAC® System was already communicating through the Demilitarized Zone (DMZ) network to multiple agencies. During the FY12 System-development period, the farthest away users were at the ARL headquarters in Maryland (~2100 miles away). This MD connection was utilized for several "live" Operational and Mobile L-REAC® System demonstrations during FY12.

The self-sustained automation and dependability of the mobile system was expected to equate the Operational L-REAC® System design. This expectation presumed that the laptop would have the equivalent input/output options as the Operational workstation platform.

Assimilating the above assessment, the "mobile" L-REAC® System "PoC" was re-defined as a system having the capability of being brought to an alternate location within a given AOI.

1.4   The Mobile L-REAC® System "PoC" Demonstration Unit

The actual Mobile L-REAC® System "PoC" demonstration unit is outlined in this section. A more detailed review is presented in the subsequent section.

OPERATING SYSTEM (OS): The Mobile L-REAC® System reduced the OS requirements from two OS (Windows and UNIX) used by the Operational L-REAC® System, to just one OS (Windows only).

NETWORK: Each Mobile L-REAC® System component was linked by specialized networks including Production Network, Standard Internet, and DMZ network.

SYSTEM OUTPUT: The Mobile L-REAC® System output consisted of the DMZ and a "local only" option. The latter selection facilitated the "stand-alone" capability needed for a mobile field unit. A feasibility study conducted in parallel with the Mobile L-REAC® System construction, added a third output option, a website link (see section 3.1).

SENSOR SUITE: The initial Mobile L-REAC® System Sensor Module utilized the original dedicated sensor suite design. This fixed sensor suite (FSS) was based on Model input requirements, and consisted of meteorological sensors mounted on a tripod. The tripod was installed on the roof of a subject building. Data from all sensors were extracted or averaged every 1 min, and archived for post-event analysis or reviews. During the Mobile L-REAC® Sensor Feasibility Study, the dedicated sensor suite options were expanded to include a MSS. This commercial MSS could be placed anywhere within the wireless footprint of the MSS communication signal. Section 3.3 elaborates on the successful study and its potential for future mobile L-REAC® System designs.

QC MODULE: The Mobile L-REAC® System-QC module was updated to accommodate both the FSS and MSS data formats.

DATA RESOURCES: Regional meteorological data (the Surface Automated Meteorological System [SAMS] mesonet) supplemented the Mobile L-REAC® System Sensor Module data.

WIND MODEL: A pre-compiled Wind Model (Three-Dimensional Wind Field [3DWF] Model-Windows Version 2) was used in the Mobile L-REAC® System Model Module. (Wang et al., 2005) The user was given three wind model scales from which to choose: building scale (5 m resolution), cantonment scale (50 m resolution) and a regional scale (100 m resolution). With the addition of mesonet data, an Objective Analysis was inserted into the data preparation routine. The 5 m resolution took between 1 and 2 min to process. The maximum processing time was 8–10 min, and occurred while running the regional scale. The highly efficient run times for each of these scales were consistent between the Mobile and Operational L-REAC® Systems.

PLUME MODEL: The Plume Model selected for the Mobile L-REAC[®] demonstration unit was a pre-compiled EPA/NOAA *Areal Locations of Hazardous Atmospheres* (ALOHA) dispersion model. As in the Operational L-REAC[®] System, specialized software, created by ARL and EPA/NOAA, was used to automatically ingest data into this model (*ALOHA User's Manual*, 2007). Display settings for the final product were chosen based on a computer screen being viewed under sunshine.

Note: The L-REAC[®] design was not limited to 3DWF (wind field) and ALOHA (plume) models. These models were chosen to demonstrate the Mobile L-REAC[®] System design.

EUD—"2 Plot" DISPLAY: The Mobile L-REAC[®] System output included the same two incident visualization windows used by the Operational L-REAC[®] System. One EUD Module-Display included a separate graphic for the wind and plume outputs. (See figure 3.) The wind model used a Grid Analysis And Display System (GrADS) (Grid Analysis and Display System, 2010) plan view of the subject area, overlaid with 2.5-m above ground level (AGL) wind vectors, wind streamlines, and color contour wind speeds. The Plume Model output showed a static, plan view overlaid with a multi-health impact gradient, hazard footprint. The two model plots were shown side-by-side in the EUD window. This display was automatically updated using the platform-independent Hyper Text Markup Language (HTML). The final results were displayed on the Mobile L-REAC[®] System and user's remote terminals.
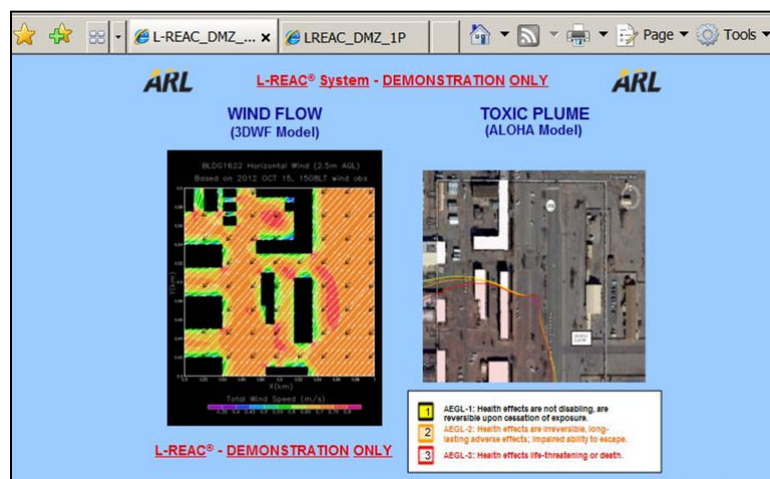
Figure 3. L-REAC[®] System EUD 2-Plot display included separate wind and plume displays.

EUD—"1 Plot" DISPLAY: A second EUD Module output consisted of a single image with both the wind and plume outputs overlaid onto a Google Earth satellite map. (See figure 4.) These overlays were written in keyhole markup language (*kml*) format. This format was chosen, so that the output could easily be re-oriented by the L-REAC[®] System Operator. The operator could zoom in until there is only one arrow in the scene,

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zoom out to show the overall atmospheric scenario, reposition the visual image to show the flow over and around the mountains versus the populated areas, or whatever was appropriate for the end users requirements.
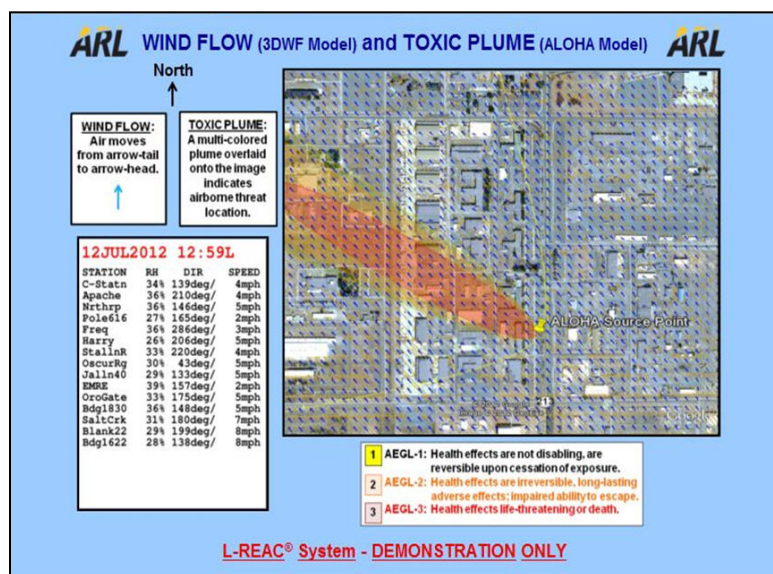
Figure 4. L-REAC® System EUD "1-Plot" display combined wind and plume fields on a single graphical background.

ARCHIVE: A Visual Basic Script performed automated archiving of output files and executed instant data QC time-series displays for each variable of the dedicated Mobile L-REAC® sensor suite.

OPERATIONS: The end-to-end Mobile L-REAC® System was designed as an automated, self sustained 24/7 system. As with the Operational L-REAC® System, the option for operator interactions was included.

EXPANDED SYSTEM CAPABILITIES:

1. A study exploring the ability for an L-REAC® System to feed its output into other SoS products was conducted in parallel with the Mobile L-REAC® System construction. When large scale disasters occur, an emergency response SoS is often implemented by government agencies. Local scale events can get lost in the SoS "big" picture technology, which is why the L-REAC® local environment output is valuable to SoS. Being able to demonstrate this capability was a significant achievement, and is described in section 3.2.

2. Shortly after the Mobile L-REAC® System was successfully built, a feasibility study showed that the original L-REAC® System "Core and Second Tier" design was achievable. The significance of this accomplishment is in the potential for

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supporting not only real-time model output but concurrently running, slower more detailed application and weather forecasting models (see section 3.4).

2. Mobile L-REAC® System

In this section, the significant design enhancements made in the construction of the Mobile L-REAC® System are detailed. The section begins with the foundational structure of the system platform and networking challenges, followed by a description of each module.

2.1   Computer System Administration and Networking

The first major change for the Mobile L-REAC® System was the L-REAC® System platform. All previous systems were constructed on desktop and workstation computer systems. This mobile system platform was on a DELL M6500 Laptop (64-bit).

The second major change was the elimination of a dual OS requirement. The Operational L-REAC® System infrastructure used a single OS, namely Windows Vista. The Linux functions were either replaced with equivalent Windows executables, scripts and programs, or, they were accommodated through a *cygwin* software package.

Another change was the elimination of the first layer, "Proto" directory. The purpose of this action was to create a more efficient, streamlined infrastructure, and to prepare the code for a DVD packaging of the product. While this change may not seem important to mention, it had a major impact on the system construction. Every program and script suddenly had a "new" location. Consequently, the code for every component and subcomponent in the design had to be updated. This action served to re-identify all the system code requirements and was a catalyst for documenting the L-REAC® System infrastructure.

The last major system administrative improvement was the addition of an alternate L-REAC® System output medium. The Operational L-REAC® System used the DMZ network to communicate with the "outside world." The Mobile L-REAC® System continued to use this method, but also expanded the output option to include a web-link (see section 3).

A general schematic of the Mobile L-REAC® System configuration is shown in figure 5. The System scripts used to initiate, automate, and terminate the Mobile L-REAC® System will be presented later, after each module has been described.
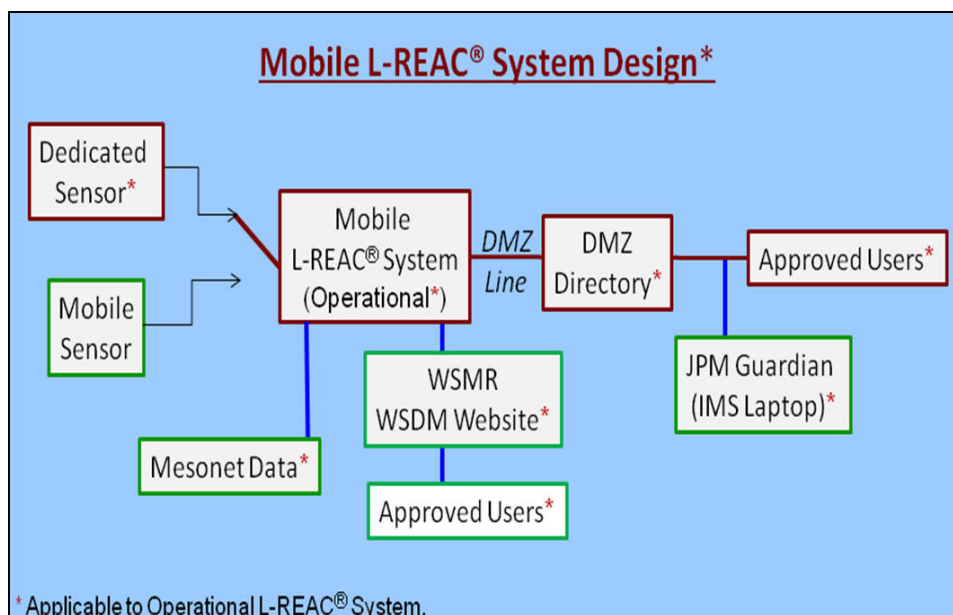
Figure 5. Mobile L-REAC® System schematic. Foundational components applicable to both the Operational and Mobile L-REAC® Systems are indicated by a red asterisk. The components managed by L-REAC® are outlined in red. The green boxes show features added through ARL collaborations (including feasibility studies).

2.2   Sensor Module

The Mobile L-REAC® System - Sensor Module supported two designs: A FSS and a MSS. For the PoC, each of these sensor types was configured to be "the" L-REAC® System's dedicated sensor. While technology and computer codes were available to ingest these two resources concurrently, government computer policy issues prevented the implementation and testing of this option.

The FSS sensor type is described in section 2.2.1, followed by an introduction to the MSS. A full MSS description is found under the feasibility studies in section 3.

Note: A mesonet meteorological data resource was ingested into the Mobile L-REAC® System. Since the "ownership" of these data were not part of the L-REAC® System Project, their physical setup and layout are not included in this report.

2.2.1 Fixed Sensor Suite (FSS)

The FSS consisted of a dedicated meteorological resource attached to and managed by the Mobile L-REAC® System. As mentioned earlier, the sensors selected were based on the model input requirements. Table 1 summarizes the variables and sensors utilized by the FSS. For a more detailed description of the Sensor Module, see *Volume 1* (Vaucher et al., 2009).

Table 1. FSS hardware. For additional information on the sensors, see *Volume 1* (Vaucher et al., 2009).

Variable	Sensor	Manufacturer	Model	Units
Pressure	Barometer	Vaisala	PTB-101B	Millibars
Temperature	Thermometer	Campbell Scientific	107-L	Celsius
Temperature/ Relative Humidity (RH)	Thermometer/ Hygrometer	Vaisala	HMP45AC	Celsius/Percent
Wind Speed and Wind Direction	Anemometer (Wind Monitor)	RM Young	05103	Meter/Second, and Degrees
Solar Radiation	Pyranometer	Kipp/Zonen	CM3	Watts/Meter^2
Micrologger	ALL	Campbell Scientific	CR23X	
Weather-Resistant Enclosure	ALL	Campbell Scientific	ENC 16/18	

The physical layout of the instruments on the 6-m tripod is tabulated in table 2. A schematic and photo of the tripod and sensor placement are shown in figure 6.

Table 2. FSS tripod layout.

Sensor Variable	Height (Above Roof Level)
Wind Speed/Direction	6 m
Temperature–Upper	5.7 m
Temperature–Lower	0.7 m
RH/Temperature	2 m
Solar Radiation	2 m
Pressure	0.25 m
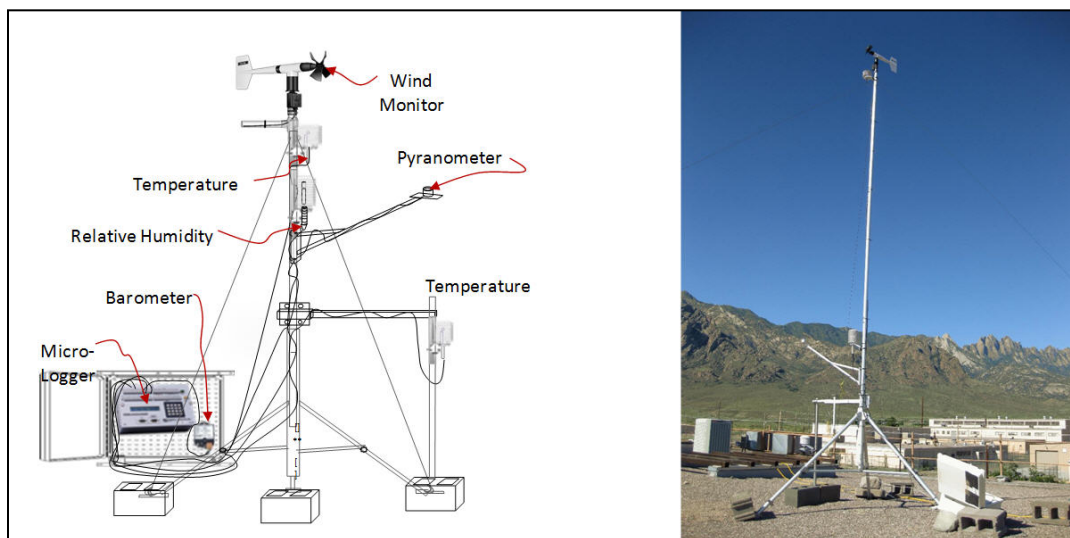
Figure 6. A schematic and photo of the Mobile L-REAC® System FSS hardware mounted on a tripod, which was located on a subject building roof.

A Campbell CR23X micrologger and an uninterruptable power supply (UPS) were co-located at the base of the FSS tripod, in a Weather-Resistant Enclosure. The micrologger sampled atmospheric conditions every 10 seconds (s), then output data in 1-min averages. For more information on the data acquisition program, see *Volume 2* (Vaucher et al., 2010).

The Mobile L-REAC® computer platform ingested the FSS data via an RS-232 connection to COM Port 1. The software managing the data ingest was the Campbell Scientific LoggerNet Administrator, Version 4.0, which allowed the acquisition programs to run as a Windows service. That is, the automated data ingest would continue, even when not attended by an operator.

To test the Mobile L-REAC® System with a fixed sensor, the FSS data were connected to a switch box via an RS-232 connection. This switch box was not part of the mobile design, but was a practical addition that allowed either the Operational or Mobile L-REAC® System to utilize the FSS resource.

Data quality control was addressed by the QC Module (see section 2.3).

2.2.2 Mobile Sensor Suite (MSS)

From the first L-REAC® System concept, the location of the potential airborne hazardous environments was expected to be random. And, the professional(s) best situated for positioning an atmospheric sensor or sensors near the hazardous area was anticipated to be a hazardous material (HAZMAT)-suited, first responder. Consequently, the MSS requirements were recognized as exceeding the common COTS meteorological sensor suite. In fact, the MSS would demand minimal time to assemble, have minimal moving parts, require near instant integration with mobile platform software (L-REAC® System Modules), operate autonomously and must be functional even within the potentially corrosive effects of most airborne hazard materials.

One sensor which matched the required description was the WEATHERPAK® Multiple Threat Response (MTR). Collaborating with the Coastal Environmental System, Inc. (CES), which later became a formal Cooperative Research and Development Agreement (CRADA) relationship, a study was conducted to test the feasibility of integrating a WEATHERPAK® MTR with the Mobile L-REAC® System. Section 3.3 presents a detailed description of this sensor and the study.

2.3   Data Quality Control Module

The purpose for the QC Module was to facilitate the operator's need to quickly review the incoming data. The script was designed for an instantaneous, midnight-to-current-time, time series plot of each data variable. Since the FSS and MSS data coming in were slightly different, the variable plots had to be modified to accommodate the data change.

Figures 7 and 8 show examples of both the FSS and MSS data QC outputs. For a detailed review of the QC Module, see *Volume 3* (Vaucher et al., 2011).
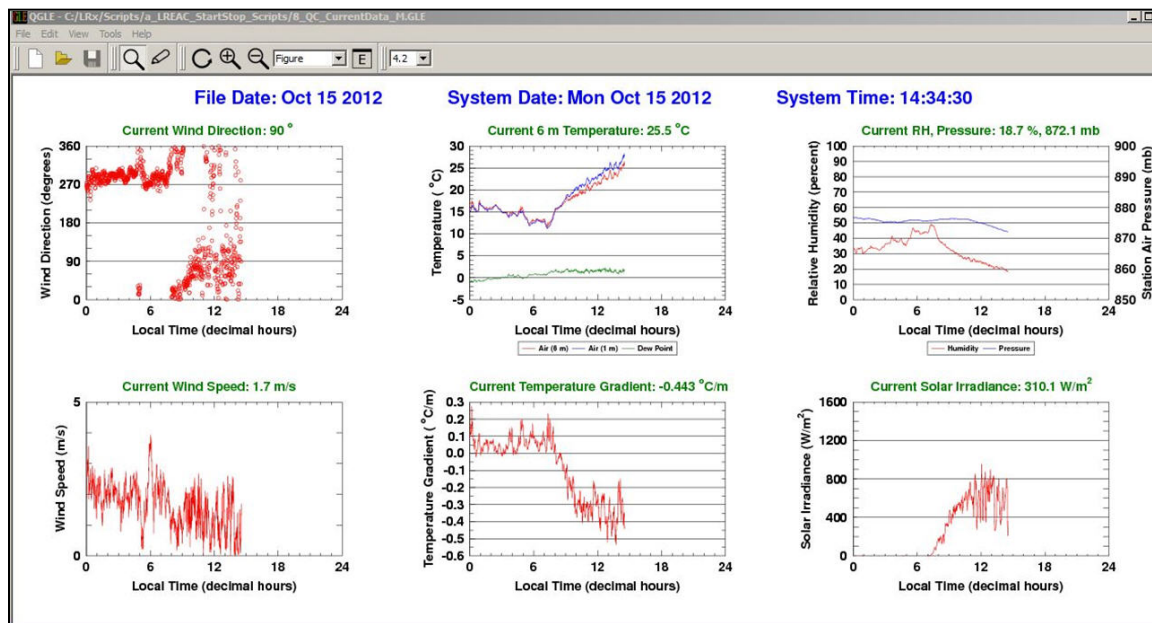
Figure 7. Example of the QC output, which assists in monitoring the FSS data. (Vaucher et al., 2011)
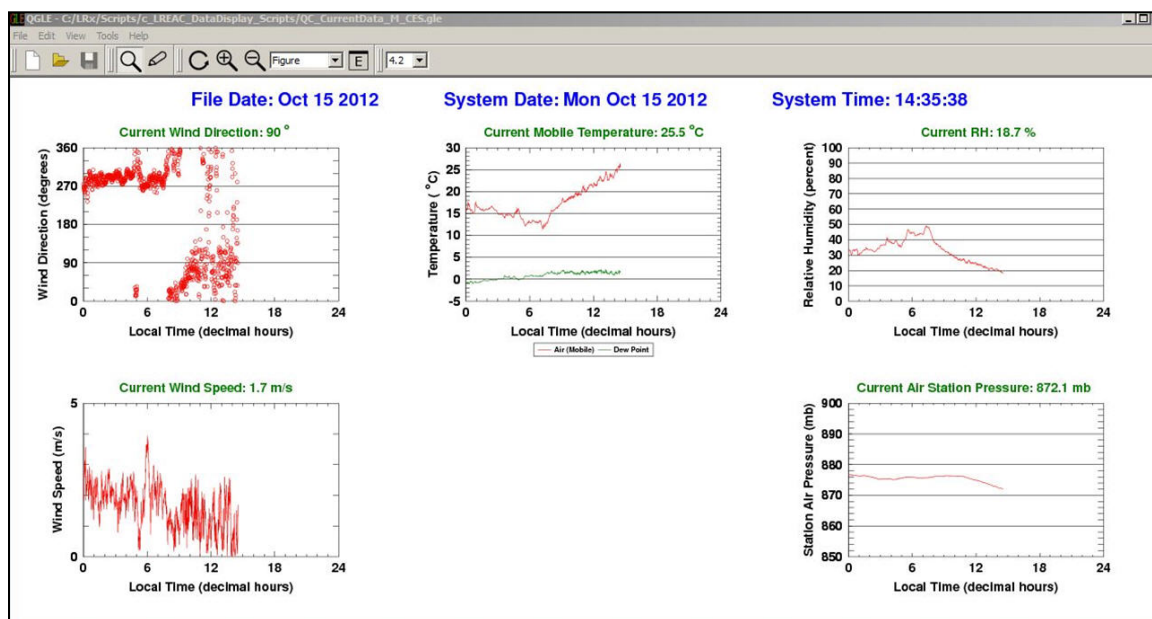
Figure 8. Example of the QC output, which assists in monitoring the MSS data.

In addition to the verification process, users could use the graphical time series to assess the environmental trends and variability. In the context of airborne hazards, such information could prove significant.

2.4 Model Module

The Mobile L-REAC®-Model Module was designed with the same three model domains as the Operational L-REAC®-Model Module. The Mobile System's user selection process for these three domains was significantly improved, as described in section 2.7. Each model scale was selected for its own application. The highest resolution, 5-m grid, was chosen as the best building scale representation (figure 9). The 50-m resolution, called "cantonment," covered the majority of inhabited areas within the given AOI, as well as the influential winds traversing the nearby mountains (figure 10). The 100-m resolution (regional scale) was chosen to capture the 50-m resolution domain and certain areas with designated importance (figure 11). To better envision the scale contrast, all three domains are displayed over a Google Earth map (figure 12).

Figure 9. Blue wind vectors show the 5-m Resolution Wind Model domain.
(Vaucher et al., 2011)
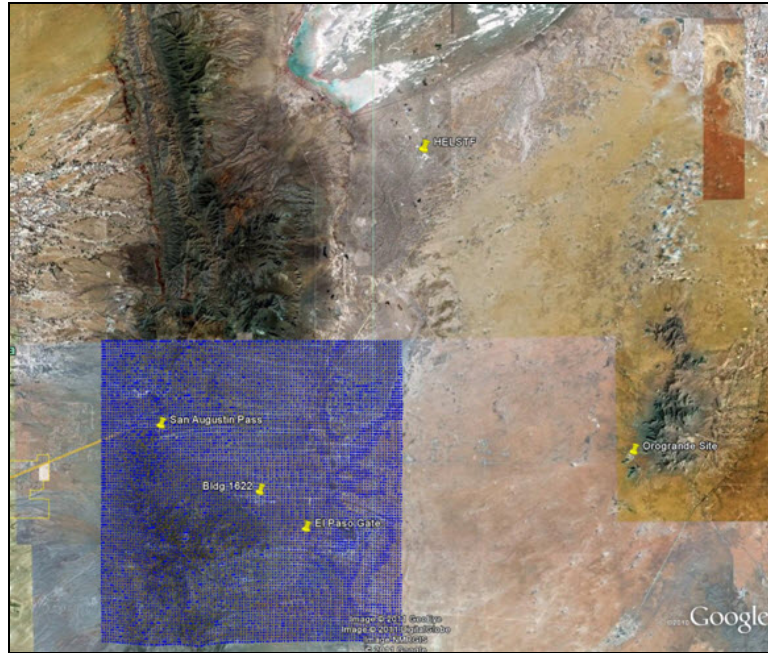
Figure 10. Blue wind vectors map the 50-m Resolution Wind Model domain; yellow streamlines show wind direction. (Vaucher et al., 2011)
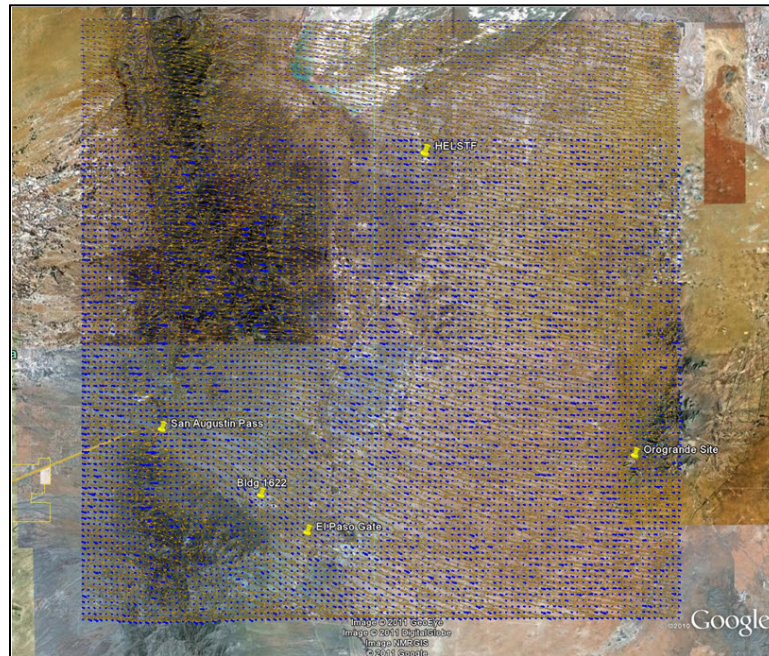
Figure 11. Blue wind vectors present the 100-m Resolution Wind Model domain; yellow streamlines show wind direction. (Vaucher et al., 2011)
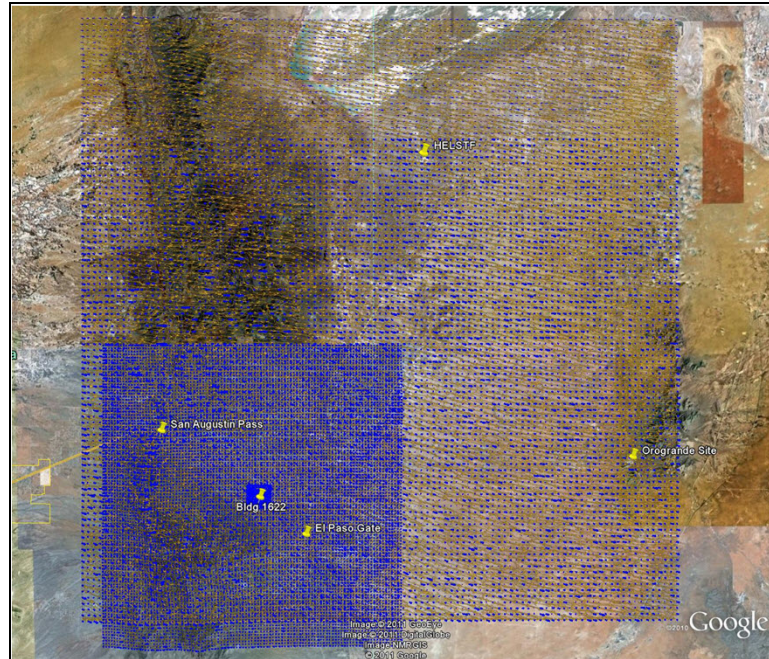
Figure 12. All three wind model domains (5 m, 50 m, and 100 m resolutions) are overlaid on a single map for comparison. (Vaucher et al., 2011)

The data QC Module provided a tool for ensuring that the best quality of "dedicated" data entered the Model Module. Mesonet surface observations and data reports supplemented the L-REAC® input, when these data were within the last 31 min. The transportable nature of the Mobile L-REAC® System had potential for limiting the access to the mesonet resource. While this physical restriction might create a slight wind model output degradation, the impact was not considered significant.

As mentioned earlier, the wind model mobilization was temporarily postponed, pending a replacement for the retired model module developer. In the meantime, the Model Module mobilization requirements for future work consist of creating a user-friendly method for updating two key model inputs: AOI terrain and building information. For the plume model-ALOHA, NOAA has provided the terrain data with significant landmark structures, on their website. For the 3DWF, there are several sources for terrain information. Most of the sources are difficult to convert into the format required for the wind model. The most promising terrain source is the National Elevation Dataset (NED), which covers CONUS at 90- and 30-m resolutions, as well as, a small part of the U.S. at about 10-m resolution. For worldwide terrain coverage, there is the Digital Terrain Elevation Data (DTED), which is available to the Department of Defense (DoD) at 30-m resolution. (Vaucher et al., 2011)

Building data are only available through restricted resources, due to security issues. ARL has investigated the use of satellite imagery and shadows to extract the relevant features. This research is ongoing.

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Model setup for a new location requires a dedicated period for gathering and processing terrain and building data. These tasks need to be done and tested, prior to the physical installation and HAZMAT response application of a Mobile L-REAC® System in a new AOI.

2.5 EUD Module

The Mobile-EUD Module design utilized the successful dual-window configuration of the Operational L-REAC® System unit. That is, one window (also known as "2-Plot" or "2P") consisted of two, independent, yet dimensionally-proportional, building scale plots placed side-by-side. The left plot displayed the 3DWF model output using a color-coded wind speed gradient and streamlines for wind direction. A time stamp in local time (LT) was included in the header, along with location identification. The right plot consisted of the EPA/NOAA ALOHA dispersion model output with a three-tiered plume footprint. Each plume tier defined a lethality impact of the chemical concentration on a human body. A local date/time box was included in the plume image. Keys for the wind and plume gradients were given within the "2P" window (see figure 13).
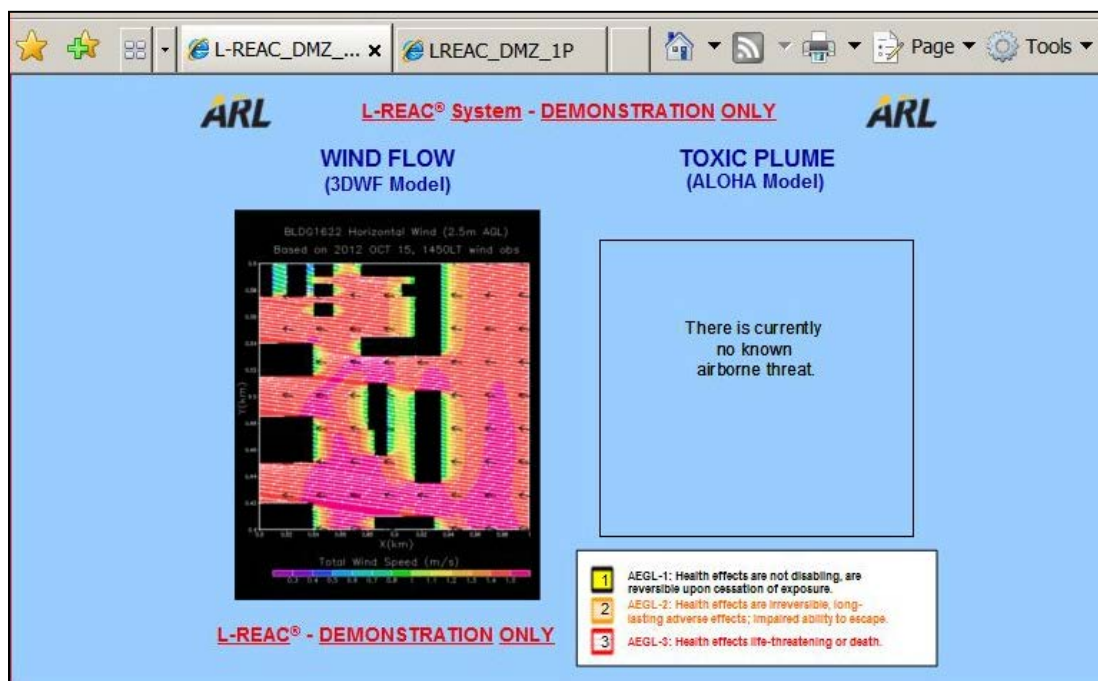
Figure 13. Example of the Mobile L-REAC® System EUD Module "2-Plot" output.

The second window (a.k.a. "1-Plot" or "1P") included a single Google Earth image with both the wind field and plume output overlaid onto this satellite imagery (see figures 4 and 14). Quantitative meteorological measurements from the dedicated sensor§ and mesonet locations were tabulated. An image of this table was placed left of the single

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§ The term "dedicated sensor" is used here, since the sensor suite referenced can be either the FSS or MSS.

plot. The dedicated sensor values were positioned at the bottom of the list, for quick reference. At the top of the list, in enlarged red font, were the date and LT of the dedicated sensor data. The time stamp was purposefully kept in LT. This decision stemmed from the fact that the system is designed for a "Local" rapid evaluation of atmospheric conditions; and, that the probability that the AOI might extend to another time zone is limited for now. The tabulated data image was included in the archived image materials; thus, ensuring time stamp documentation.
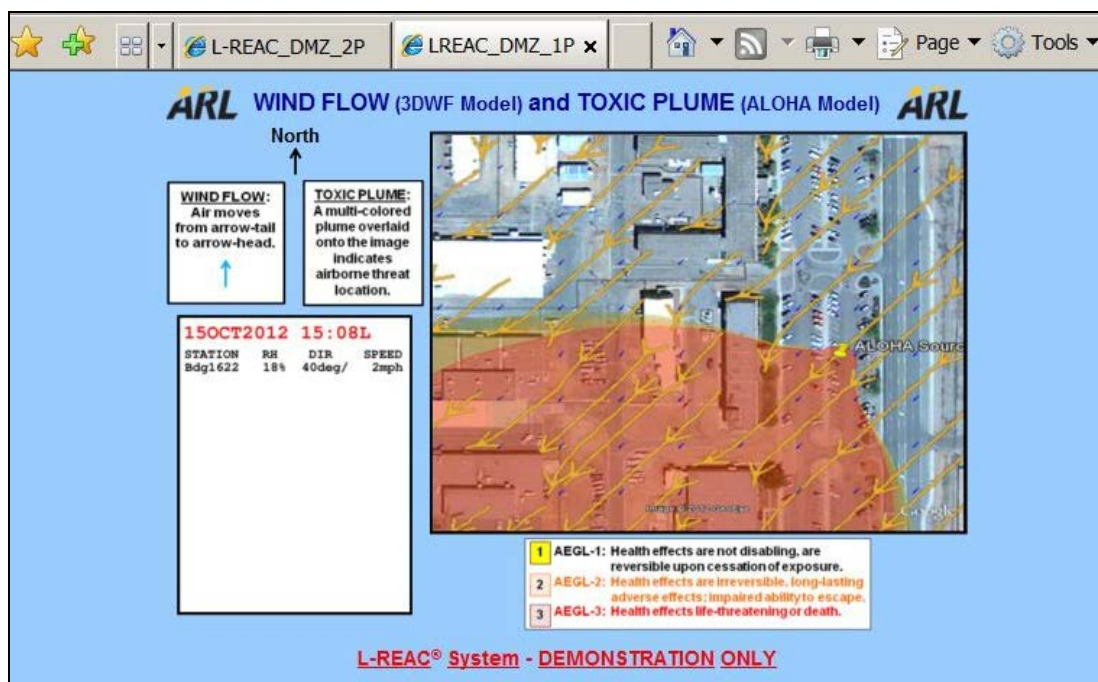
Figure 14. Example of the Mobile L-REAC® System EUD Module "1-Plot" output. Note that even with only the dedicated sensor working, the wind and plume fields can still be generated.

The "1P" image could easily be reoriented in the horizontal or vertical (zoomed-in and –out) by the L-REAC® operator. An icon function called "Instant Save" provided the operator with the ability to communicate any new image orientations to the end users. The time needed to go through the instant save routine was between 20–28 s.

If no toxic plume was present, a default text indicating "no known airborne threat" replaced the plume entries on both windows. As new wind model runs were completed, the images on both the EUD windows were automatically updated.

The Mobile L-REAC® System design continued to use the automatic Wind and Plume (if applicable) Model output updates of the Operational System. That is, specialized JavaScript code was integrated into an HTML program, and a winBatch executable.

Another significant EUD change was the acknowledgement of the registered "L-REAC" trademark. In short, the "L-REAC™" was changed to "L-REAC®".

The method of communicating between the Mobile/Operational L-REAC® System platform and the user is described in section 3.1.

2.6   Archive Module

Three options were included in the L-REAC® System archive capabilities: storing a copy of all ingested dedicated (fixed/mobile) data as they come in, creating a single day's worth of ingested data file, and preserving the L-REAC® images sent to the end users. These capabilities were successfully transferred from the Operational to the Mobile L-REAC® System. Each archive capability was executed as follows:

- When L-REAC® utilized the Loggernet ingest software, the option to create a backup copy of all ingested data was purposefully selected during the L-REAC® integration process.

- Once a day, an automated L-REAC® Archive Module script extracted and labeled a single day's worth of data from the "live" L-REAC® Sensor Module data file. To re-view a whole-day of data from the archive, the user activated an archive display script. The resulting plot was similar to the QC time series, except that the "current" value headers above each plot were replaced by diurnal averages (for wind direction), maxima (for wind speed and solar irradiance), or maxima/minima (for air temperature, temperature gradient, RH, and station atmospheric pressure). These time series started at mid-night and ended at 2359 LT (see figure 15). Adjustments were made on the mobile system to accommodate the FSS and MSS data formats. For more details of the Archive Module see *Volume 2* (Vaucher et al., 2010), and *Volume 3* (Vaucher et al., 2011).
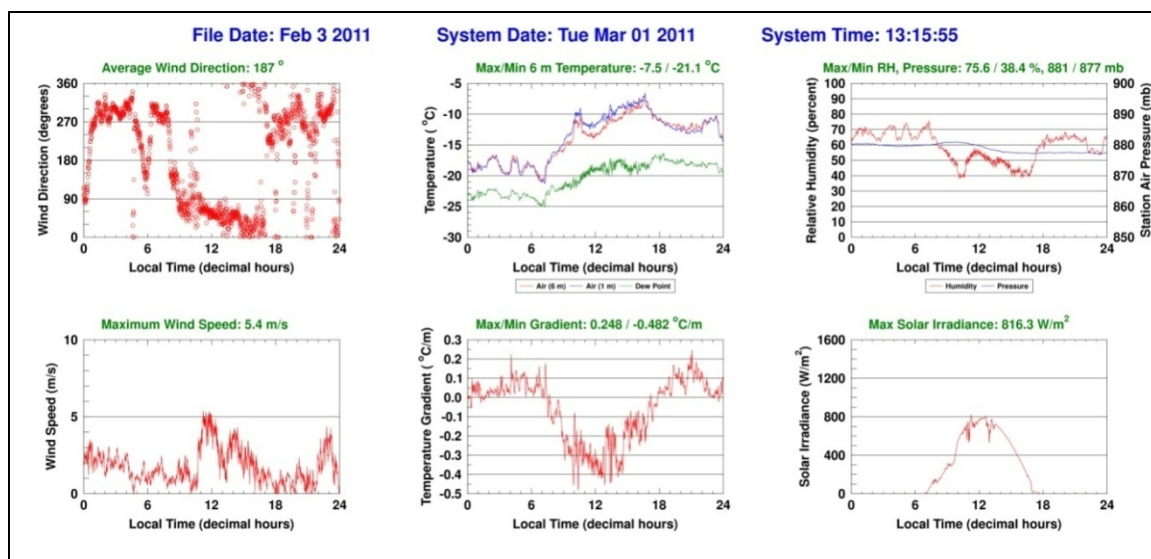
Figure 15. The archived FSS time series display allowed the end user to re-examine a whole-day of
1-min data for post-incident investigation.

- To preserve the L-REAC® images sent to the end users, a supplementary function
  within the EUD module was activated. The date/time reference in the assigned
  archive filename collated results and allowed all five core images to be copied as a
  set into a designated archive directory for future reference.

Each of these archiving options allowed the end user to re-create incident scenarios.
With the ingested data (FSS/MSS), the wind and plume models were able to be rerun and
output re-generated in a continuous data stream. With a day's worth of data, a specific
date of interest could be extracted from the multiple years of archived data, wind/plume
models re-run and output regenerated. With images collated by date/time, a time-
sequenced movie of the outputs could be assembled, or the user could insert the outputs
into an L-REAC® HTML directory and review them.

2.7 Scripts and Automation

Three categories of scripts were used by the Mobile L-REAC® System: The *Startup*
scripts, Scripts to view L-REAC® products, and the *Shutdown* scripts. A description of
each script category follows.

2.7.1 L-REAC® System *Startup* Scripts

One of the more significant improvements was in the redesign of the *Startup* scripts. The
two-step process of the Operational L-REAC® System was preserved. In step one, there
were no changes for the FSS design. The user double clicked on a script that initiated the
data conversion routine for the plume model. In step two, the Mobile System user no
longer had to discern which second script file to activate. For example: The Operational
System user was given a choice of six scripts: one script for each of the three model

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resolutions without archiving the results, and one for each model resolution with the archive option turned on. When the method of communication expanded to include a website access (see section 3.1), these six options doubled. When the option for restricting the output to just the local platform was added (Mobile System only), the options again gained six more variations. The thought of adding any variation to the three output selections (DMZ, web, local) grossly exceeded the user-friendly criterion, and another solution for the Mobile System design was sought.

The result was a simple graphical user interface (GUI) using the available software tools. For the Mobile System-Step 2 of the *Startup* was a series of windows. The user had the option of selecting a default setting of:

- 5-m resolution wind model run (fastest model run),

- a local output display only, and

- no archiving of the images (see figure 16).

If this option was selected, the user then proceeded to initiate both the wind and plume models via the GUI guidance provided.
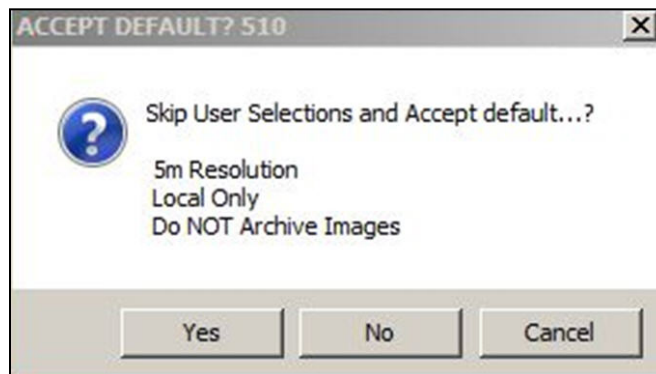
Figure 16. L-REAC® System *Startup* Script offers a default selection for the (1) Model Resolution-5 m Resolution, (2) Output Options (local only) and (3) Archive Options (do not archive). If the default is not selected, the user proceeds to the individual selections.

If the user did not select the "default setting" for Step 2 *Startup*, then a window with each of the three categories of options was provided. First, the user selected a wind model resolution (figure 17a):

- 5-m resolution (building scale).

- 50-m resolution (cantonment scale).

- 100-m resolution (regional scale)

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The location for displaying the output was chosen next (figure 17b):
- Local only—meaning just the L-REAC® System computer.

- Local and DMZ—meaning the L-REAC® System computer and a restricted-access DMZ network drive.

- Local, DMZ, and website—meaning the L-REAC® System computer, a restricted-access DMZ network drive and controlled access website (see section 3.1).

And finally, the user decided the image output archive option (figure 17c):
- Archive Images.

- Do not Archive Images.
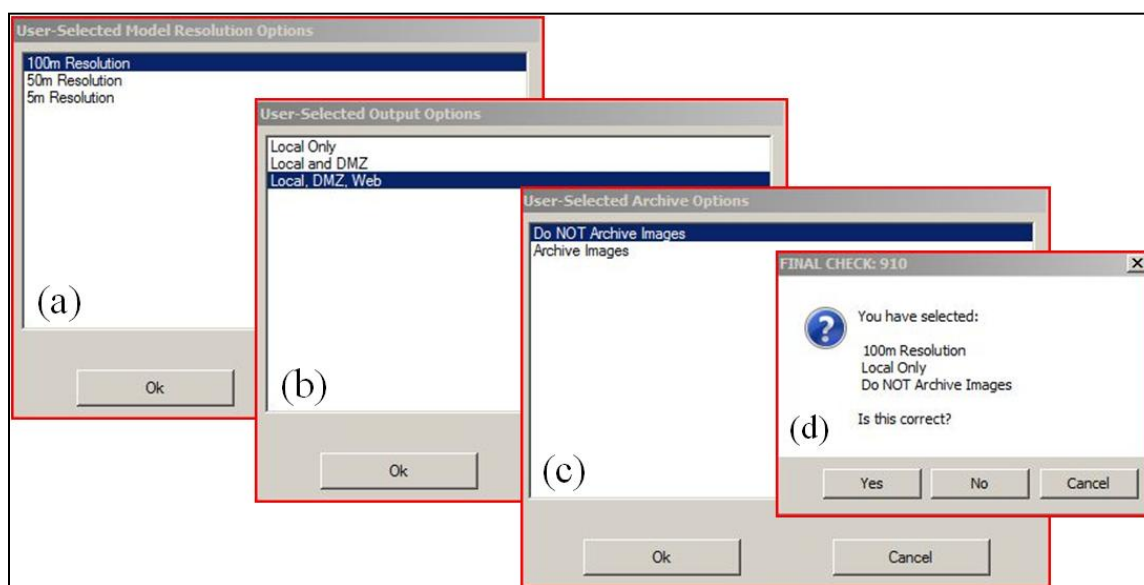
Figure 17. User selections for the L-REAC® System *Startup* Script consist of three choices: (a) Model Resolution, (b) Output Options and (c) Archive Options. The selections were reviewed (d) before initializing the models and output.

Once the options were chosen and confirmed, the user utilized the subsequent GUI guidance to initiate the wind and plume models. A small but "friendly" automation was added to the plume model startup. When the *IAT Test* function was begun, the script included an automatic turn on of the sensor monitoring function and a minimization of the window. On the Operational L-REAC®, these two actions were executed manually.

When no plume model was required during the *Startup*, the plume model software still ran in the background, waiting for the chemical data to be defined. As mentioned earlier, for "no plume" scenarios, the end user was informed on the EUD Module-Display that "There is no known airborne threat."

2.7.2 Scripts to View L-REAC® Products

The authorized end user was able to access the Operational and Mobile L-REAC® Systems output products through HTML programs that remained resident in a designated DMZ directory. These programs were concurrently stored locally on the Mobile System, and the approved DMZ remote site location. A special executable was iconized on the DMZ directory. The approved user could copy this icon onto their desktop. They would then be able to double-click on the icon, to initiate the L-REAC® EUD Module-Display HTML programs, which would subsequently commence automatic updates every 30 s.

2.7.3 L-REAC® System *Shutdown* Script

Another significant "friendly" improvement was in the *Shutdown* Script. When the Mobile L-REAC® System was no longer needed, the operator of the L-REAC® System utilized a "shutdown" script. This single script terminated all Mobile L-REAC® System software, except the LoggerNet, the mesonet data ingest, and the daily Archive Module. These three functions remained as background jobs, in preparation for future operational L-REAC® System usage. The shutdown script also replaced all the automated images on the user's EUD, with "L-REAC® is off-line" images.

Two additional "user- friendly" features were added to the Mobile System:

1. The Mobile L-REAC® System operator was given the option of shutting down the L-REAC® software functions on the local computer only. This choice would enable the Operational L-REAC® System to continue servicing the users, after the Mobile System's contributions were terminated. Also facilitated was the ability to test the Mobile System locally, without impacting the "real-world" service provided by the Operational System.

2. The Operational L-REAC® System shutdown procedure required the operator to acknowledge the termination of each software function, including the three minimized, command-windows created by scripts. The Mobile *Shutdown* script zipped through each software function, with the computer acknowledging each termination. What used to take up to 30 s was reduced to about 2 s.

3. Four Feasibility Studies and Their Implications

Four L-REAC® feasibility studies were conducted in FY12. These included: expanding the output options to include a website, integrating the L-REAC® output into a SoS, augmenting the dedicated sensor choices to include a mobilized sensor unit and

simulating a multi-processor L-REAC® System design. Each study represented a starting threshold for a wide variety of potential L-REAC® Project growth and will be described separately.

3.1 L-REAC® Website—An Alternative DMZ

The successful website design was a product of several iterative steps. In the following three sections, the evolution of the web output design is recounted, followed by a description of the "final" website and a sample of key benefits gained with this "new" System feature.

3.1.1 L-REAC® Website Background

The first L-REAC® output display used a Sony Vega Plasma high definition television (HDTV) screen located in an ARL office building lobby and a SIP room computer with a digital screen projector. These displays were linked by a local network. When non-ARL emergency professionals requested access to the real-time L-REAC® System output, a procedure to manually transfer the approved output onto a restricted-access website was developed. This procedure was operator-intensive and subject to numerous website hurdles. Despite the awkward process, the successful network communication established the web media as a real possibility for future system communications.

The subsequent L-REAC® System constructed ("Prototype") simplified the complexity of the remote access methods by automatically sending the results to an approved ARL Production Network, shared drive. This endpoint was linked to interested end-users and pre-approved locations (such as SIP locations and the Emergency Operations Center [EOC]). A user accessing the shared drive was able to copy an iconized executable to their PC desktop. With a double click of their mouse on this icon, they would then initiate the two L-REAC® HTML windows. The L-REAC® output and automated updates would continue until the user closed the two windows. Flat files of the wind and plume plots were included on the shared drive, in case end users needed to copy these files into an e-mail for an emergency response decision maker.

When L-REAC® files disappeared from this internal shared drive, computer security increased the safeguard requirements of the communication method. Consequently, the Operational L-REAC® System EUD-output was redesigned; a physical DMZ network was installed and an access-restricted directory on this DMZ network was created. With this new DMZ method, only pre-approved remote site users from various DoD organizations could initiate a link to and receive subsequent automated updates from the L-REAC® System. As before, the L-REAC® link was packaged in an icon that could easily be copied onto the user desktop and, the L-REAC® output remained visible from the user's PC until the user closed the two HTML-based windows.

The DMZ directory continued to include flat files of the wind and plume plots. This feature remained, so that users had the option of e-mailing needed information to hand-held Blackberry devices in the field. While ambient sunlight and small screens made viewing the results on these hand-held devices challenging, the concept of using a diversity of platforms for the L-REAC® output was established.

The DMZ network was approved by ARL, but only as a "temporary" solution. The search for a user-friendly L-REAC® web-link design continued in parallel with the Mobile L-REAC® System development.

Aside: At the time of this writing, approved users of the Operational L-REAC® System output included the WSMR–Directorate of Emergency Services (DES)\Fire Department, the WSMR–EOC, WSMR–Information Management Directorate (IMD), the WSMR–Plans, Analysis and Integration Office (PAIO) , WSMR Plans and Operations, approved ARL workforce from three different directorates, and the ARL SIP room.

3.1.2 The L-REAC® Website

In the spring of 2012, the L-REAC® System was introduced to the WSMR-IMD. Their enthusiastic response led to a very fruitful interaction with the White Sands Data Management (WSDM) webmaster. Based on externally-established web design requirements, the automated plume image had to be reformatted. All code involving the creation and distribution of this image was also changed. The registering of the "L-REAC" trademark coincided with the web-link development; consequently, all system logos were updated. The security restrictions continued as part of the EUD web-design and were co-managed by the webmaster and ARL. Tests were conducted regarding access by unauthorized users. The results confirmed that the L-REAC® System output was secured from unauthorized entries.

The L-REAC® System website design did not use two separate windows; instead, the two window outputs were layered. The "1P" output greeted the user, as the user entered the website (see figure 18). In the upper left corner, the "L-REAC®—Building Scale" text could be clicked on, so that the "2P" display would replace the "1P" (see figure 19). A click on the upper left "L-REAC®" text brought the user back to the "1P" display. Next to these text options was a box for communicating messages to end users. A standard government disclaimer was added to the bottom of the window. The programming code for this website was masterfully created in compliance with government/army website standards.

Figure 18. L-REAC® System Website on WSDM. "1P" Display.

Figure 19. L-REAC® System Website on WSDM. "2P" Display.

The WSDM website ran 24/7, with the L-REAC® output perpetually updating.

When the L-REAC® operator selected both, the DMZ and web-link options, then the L-REAC® scripts would first update the DMZ files, immediately followed by the L-REAC® website. The ownership of the website belonged to WSMR. ARL worked collaboratively with WSDM administrators on this task.

3.1.3 Benefits of a L-REAC® Website Link

The first major benefit of the web-link feature was the potential ability for ARL and WSMR emergency response crews to view the output via any DoD-issued, HTML web-based medium, including HTML-friendly, hand-held devices.

Another benefit was the release from a computer-specific access requirement. The DMZ users were limited to viewing the output from a pre-approved, government issued PC. With the web-link, the pre-approved users were required to have a verifiable DoD association only; the PC was not a factor. For emergency first responders who naturally access multiple computers during the course of an incident, this liberation simplified matters significantly. If an incident had power outages, users could re-connect via another remote site PC without delay. Or, if the DoD worker had their PC updated, the fact they were using a "new" PC would not block their ability to receive this potentially life-saving information.

3.2 Integrating L-REAC® into a SoS

Being able to integrate L-REAC® output into a SoS is an attribute that proved L-REAC® is able to contribute to already established, large scale SoS tools. In the following three sections, the reason for pursuing this feasibility study is explained, the integration design and results are reported, and the opportunities that could come from this successful study are described.

3.2.1 SoS Background

On September 11, 2001, two World Trade Center towers in New York City were suddenly taken down by terrorists. The United States subsequently initiated several large-scale, emergency response programs. As part of these programs, a gleaning of the best contemporary technology was undertaken. Various atmospheric models and counter-terrorist software applications were already available; therefore, it seemed reasonable to integrate these many resources into a single SoS. After adding a GUI wrapper that tailored the SoS for large scale applications, the heavy investments made by emergency response managers and large corporations had a tangible tool worthy of any future large-scale assault on the American public.

Concurrent with the SoS development, ARL was learning more about the urban environment and how to communicate the most relevant, local-scale, atmospheric

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information to emergency first responders in a timely manner. By the time the L-REAC®
System had congealed into an operational decision aid, the larger SoS were well
established. The one void in the SoS design though, was in the local scale. The L-
REAC® near real-time communication of local atmospheric conditions made this decision
aid attractive to the SoS community. Unfortunately, it was still unknown if the L-
REAC® System could be integrated into an established SoS. When a representative from
Fort Bliss, TX, Directorate of Plans, Training, Mobilization and Security (DPTMS) Plans
and Operations (P&O) attended the *L-REAC® System Open House* (120228), the
opportunity to test the feasibility of bringing L-REAC® output into a SoS under the "Joint
Project Manager (JPM) Guardian" Program, followed.

The Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD)
hosted this JPM Guardian Program. The JPM-Guardian Program provides chemical,
biological, radiological, and nuclear (CBRN) defense capabilities for homeland and
installation defense, as well as vigilant protection and initial response for the DoD critical
infrastructure and civilian support (JPEO-CBD, 2012). Bringing several large scale
atmospheric, transport and dispersion models onto a single computer platform (a SoS)
was accomplished by the JPM Guardian Program. The results were placed on an Incident
Management System (IMS) computer. Through the Fort Bliss connection, ARL was
loaned an IMS laptop. This laptop contained a product of the JPM Guardian SoS called
"Consequences Assessment Tool Set," Version 6 (CATS6). According to the Science
Applications International Corporation (SAIC) publications (Consequences Assessment
Tool Set [CATS], 2012):

> "*CATS is a consequence management tool package that integrates hazard
> prediction, consequence assessment and emergency management tools (including*
> Hazard Prediction and Assessment Capability(*HPAC)) with critical population
> and infrastructure data, all within a commercial Geographical Information
> System (GIS). CATS uses its constituent tools and data to predict the hazard areas
> caused by chemical, biological, radiological, nuclear and explosive incidents, as
> well as earthquakes and hurricanes. CATS helps to estimate collateral damage to
> military, civil and industrial installations, assesses associated casualties and
> damage to facilities, resources, and infrastructure and creates mitigation
> strategies for responders.*"

This CATS6 software was what ARL used to show the feasibility of bringing L-REAC®
into a SoS, which will be reported in the next section.

3.2.2 Step 1: Automated L-REAC® Output Sent to the IMS Laptop

Before the system integration could occur, a plan for how to bring a non-ARL laptop into
the L-REAC® network had to be created. ARL consulted ARL's contracted network
expertise. An inspection of the network ports narrowed the original dual location plan to

a single location. The next step was to explain this plan and secure several layers of ARL permissions from various ARL computer/security authorities. In the course of this step, parts of the freshly imaged laptop from Fort Bliss had to be "updated" to comply with ARL standards. Unfortunately, these updates would later block full access to the JPM Guardian software.

With the approvals secured, ARL's contracted computer associates completed their task of constructing the physical and software network links. The equivalent of a DMZ handshake between systems was established. Almost instantly, the two systems were able to recognize each other, and the two standard L-REAC® output windows were running with their automated image updates. This design ran without operator intervention for several hours. Occasionally, the screen saver would interrupt the visual display, but the automated L-REAC® image transfer persisted without disruption. Using the screen saver password, the visual display returned, confirming that the automated integration of the L-REAC® output onto a SoS device was working, successfully.

3.2.3 Step 2: L-REAC® Output Integrated in SoS

The second step to this study was to bring an L-REAC® System image into a SoS tool. The SoS tool chosen on the IMS laptop was CATS6, a consequence management tool package developed by SAIC. CATS6 produces layers of emergency response information united by a common baseline map (see section 3.2.1). The atmospheric model selected to collate L-REAC® output was the HPAC Model. Due to the proprietary nature of the CATS6 software, a static L-REAC® output insertion was pursued. The image was transferred as one of the flat files on the equivalent DMZ connection. The L-REAC® image was inserted as an overlay, using latitude/longitude references. A subsequent run of the HPAC Model produced a set of plume outlines showing hazard concentration gradients, as they would impact human life. These plume layers were placed on top of the imaged wind field, confirming the potential for the L-REAC® to insert "final" image products into a SoS tool. Figure 20 shows an example of the results.
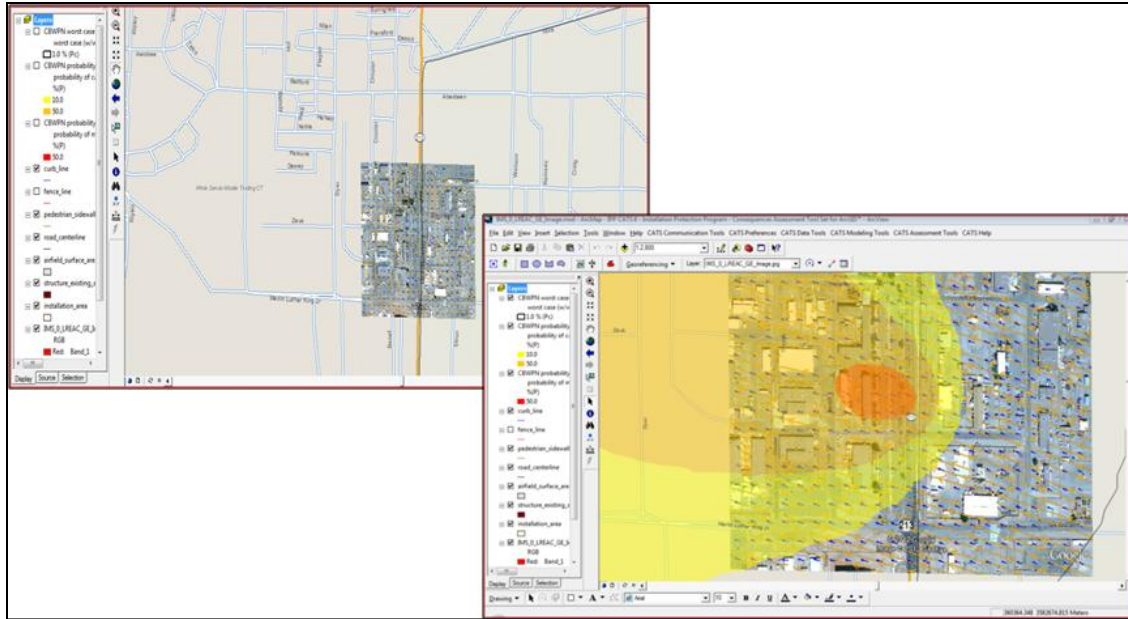
Figure 20. L-REAC® System wind field was inserted as a layer between the foundational CATS6 mapping display and the HPAC-generated plume, successfully showing the feasibility of ingesting L-REAC® System output into the JPM Guardian SoS.

Since the wind field image was created from automatically linking latitude/longitudinal vectors over a Google Earth map, the potential for these same wind vectors to be automatically transferred into the latitudinal/longitudinally-anchored CATS6 display was implied. The file containing the mapping references was a *kml* file. CATS6 had a conversion file for mapping these data. However, with the required system "update" that authorized bringing the ARL and IMS systems together, this conversion program was inaccessible. As Army computer standards align, the conversion and subsequent mapping will no doubt be possible. In the meantime, the flat file image was successfully inserted between the baseline map and the HPAC plume overlays, further confirming the feasibility for L-REAC® to operate as part of a SoS.

3.2.4 Impact of the SoS Feasibility Study

The L-REAC® Project first encountered the established SoS while investigating the potential applications with the National Aeronautics and Space Administration (NASA) sites. One of the satellite NASA sites is near WSMR. Since their atmosphere can impact WSMR, the Operational L-REAC® System 100-m resolution model AOI overlapped this NASA site. During conversations with NASA emergency management, we were introduced to NASA's SoS. Without experience in feeding the L-REAC® System output into a matured SoS, we elected to not pursue this collaboration. However, with the SoS capability proven, this potential joint venture could be reopened.

Fort Bliss had an interest in the L-REAC® for the reasons cited above; L-REAC® fills a vacant niche by providing timely and relevant *local* atmospheric intelligence. Other government and civilian locations using large scale emergency management technology could also benefit by adding the L-REAC® to the suite of tools within their SoS. With the success of this feasibility study, the next step is the opportunity to implement this design operationally.

3.3   Mobile L-REAC® System with a Mobile Sensor Suites (MSS)

The successful Mobile L-REAC® System with a FSS provided the foundation for the third feasibility study. That is, investigating the feasibility for augmenting the FSS sensor choice with a MSS option. The next sections describe the background for this study, the MSS utilized, the Mobile L-REAC® System design, and the potential future for this design.

3.3.1 Mobile Sensor Background

The L-REAC® System design can accommodate multiple applications. However, the foundational application was responding to hazardous airborne material incidents. The location of these potentially lethal environments was always expected to be random. The personnel best situated for strategically placing an atmospheric sensor or sensors in an in situ hazardous area were expected to be wearing the standard personal protection equipment—a HAZMAT suit. With this protective clothing comes a reduction in detailing dexterity or motor skills. Consequently, any mobile sensor selected for a HAZMAT site installation, needed to minimize all small, fine-movement requirements. Attaching cables, tightening bolts, keyboard typing were all subject to intense designer scrutiny.

When the initial L-REAC® sensor suite was chosen, this selection was based on construction logistics. Wireless technology was available, but not readily accessible at most government facilities due to security issues. These limiting factors, forced the vision for a mobilized L-REAC® design to be temporarily suspended, while the fixed sensor suite design, with hardwire and cable connections in place, was implemented. Fortunately, policies and technology improve over time. Recently, the opportunity opened to utilize wireless technology within reasonable restrictions. The next step was selecting the appropriate sensor.

The purpose of the MSS was to provide L-REAC® with in situ measurements. Data points from the onsite location would especially strengthen the applicability of the plume model output. Since the HAZMAT responder attire would restrict the professional's movements, the qualifications for a MSS could not be a standard COTS meteorological sensor package. After investigating various options, the CES WEATHERPAK® MTR distinguished itself as fitting the sought after requirements.

3.3.2 Mobile Sensor Suites (MSS)

The Mobile L-REAC® System with MSS feasibility study utilized the CES WEATHERPAK® MTR (see figure 21). The sensor suite measured wind speed and direction, air temperature, relative humidity and pressure. The suite had a Global Positioning System (GPS) and built-in compass for an automatic determination of True North. This automatic north alignment feature was an instant time saver for the sensor suite setup. Data were sampled every second and the system computed a 5-min running average. Data were transmitted via wireless technology, every 30 s to a display. The demonstration unit utilized an "ultrasonic" anemometer. The sensors were housed in a 6061-T6 aluminum, non-corrosive, non-sparking alloy, mounted on a 3-m tower. The setup procedure was intuitive and executed in less than 1 min, even when dressed in a HAZMAT suit. The single twist, latching mechanisms facilitated the extremely efficient sensor and tripod setup. Ten D-cell batteries allowed the system to continuously operate at any location, within the radius of the wireless signal, for 2 to 3 days. (HazMat/First Responder WEATHERPAK®, 2011) For testing and demonstrations, the more economical hardwire power to the MSS was utilized.

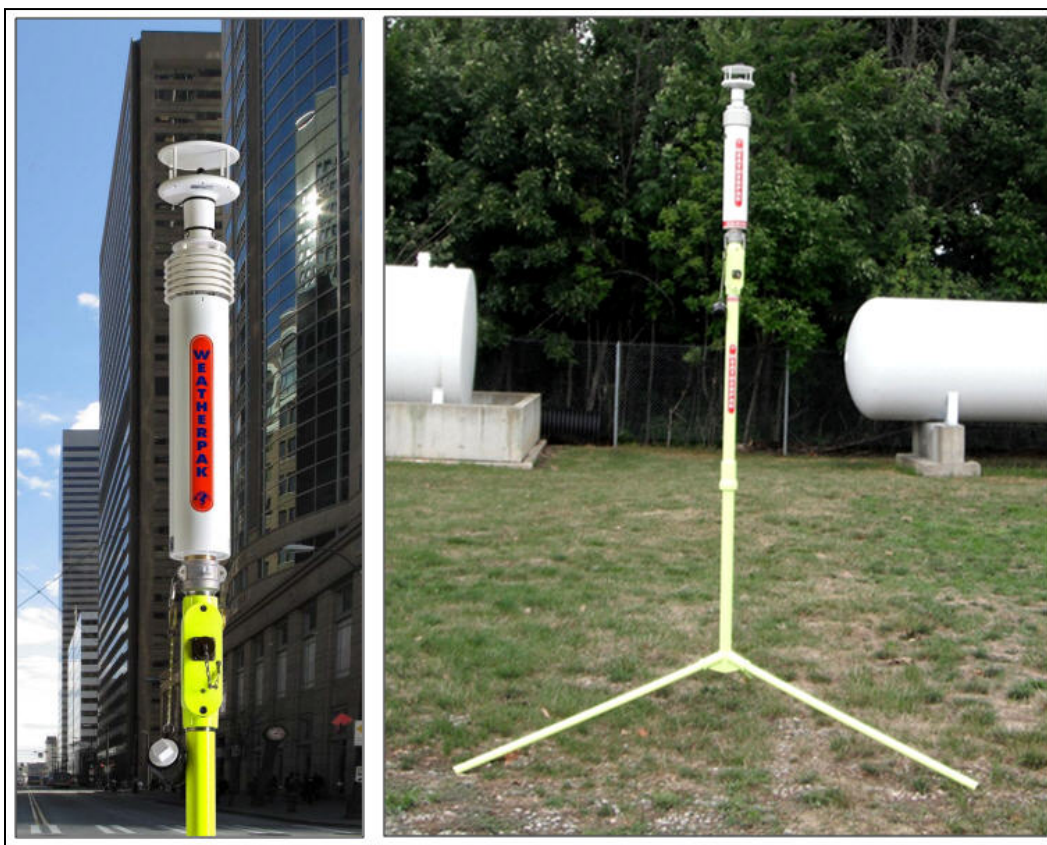
Figure 21. The wireless WEATHERPAK® MTR (left image) was used as the MSS in the Mobile L-REAC® System Feasibility Study (HazMat/First Responder WEATHERPAK®, 2009/2011); The MSS sensor/tripod were assembled in less than a minute (right image), and can be done while wearing HAZMAT protective gear (Personal Communication, 2012 December).

3.3.3 The Mobile L-REAC® System Design with MSS

The Mobile L-REAC® System design included a Vista OS platform on a laptop, the updated, more user-friendly *Startup* and *Shutdown* scripts (see section 2.7), the Sensor Module (with both FSS and MSS data acquisition scripts), the Model Modules (wind and plume models), the EUD Module, the QC Module (with plots that accommodated a MSS modified data format), an Archive Module, and the ability to automatically output to the local laptop, DMZ site and/or, the website end points.

The MSS chosen for the feasibility and subsequent demonstrations was the WEATHER® MTR. This sensor package came with data acquisition software called "INTERCEPT." Unfortunately, ARL computer policy personnel would not approve INTERCEPT for operational usage on the ARL network. Consequently, ARL wrote their own code to ingest the data. Two versions of this code were created: one that ingested data via "Putty" and the other utilized a more contemporary software tool, "Powershell." Both ingest routines used a Windows-based script to convert the data into L-REAC® format, which then propagated through the L-REAC® System in the same manner as the ingested FSS data.

The original FSS format was designed to accommodate multiple wind and plume model selections. Therefore, the ingested FSS data format included some "extra" variable entries. The MSS ingested only the data that were critical to the demonstration unit models. When the MSS data were converted into the FSS format, there were a few unfilled variables. A placeholder space was inserted by the conversion program for any data that was technically "missing." The subsequent data processing time interval of the MSS showed no significant difference from the Operational L-REAC® System with a FSS. The QC and Archive plot outputs were adapted to the revised data formats (see section 2.3).

To operate the Mobile L-REAC® System—permission to run the wireless MSS technology had to be secured. Then, the MSS could be assembled and placed within the radius of the wireless signal. Hard power was utilized for the MSS during the study, but not required, as explained above. The two-step software *Startup* routine was equivalent with the Operational System. Once initiated, the System would run unattended, just like the Operational L-REAC® System. When the operator wished to shutdown the system, the operator could opt to shutdown the program locally (not sending "offline" messages to the end user displays), or fully (which informed end users that the System was "offline"). This latter feature allowed the Mobile L-REAC® System to supplement and function independently from a concurrently-run Operational L-REAC® System. This advantageous dual processor design is elaborated on in section 3.4.

3.3.4 Potential Future for the Mobile L-REAC® System Design

The potential applications of a Mobilized L-REAC® System design are as numerous as the applications for the L-REAC® System. Examples include mobile fire fighters, mobile SWAT teams, mobile military units such as first-in reconnaissance, etc.

One of the foremost questions asked by users who witnessed the Mobile L-REAC® System for the first time was: How many Mobile L-REAC® Systems can we put in the field? In other words, could multiple MSS be scattered around an airborne hazard zone?

L-REAC® already uses a mesonet of meteorological sensors. The use of multiple MSS would follow the same pattern. Based on the current ability to ingest mesonet data and CES's verbally conveyed description of their successful use of multiple, wireless WEATHERPAK MTR systems, the concept of using multiple MSS with the L-REAC® System, was assessed as reachable. (Personal Communication, 2012 February 28)

Another potential mobilization vision involves linking the vehicle-mounted CES-MSS with the L-REAC® System. This design would be useful for both civilian and military applications.

Finally, there is the concurrent utilization of both the FSS and MSS. This design was actually executed during the fourth feasibility study, which will be described next.

3.4 Validating a Multi-processor L-REAC® System Design

One of the original L-REAC® System visions was to build a time-efficient, measurement-model-display "core" system, with additional slower running models running on a second "tier" or independent computer processor (see figure 22). In this design, the "core" system would continuously service users with the automated, timely and relevant quick running model outputs. When the "second tier" completed generating its results from the slower, more detailed models, the mapped results would supplement the "core" system output sent to the users.
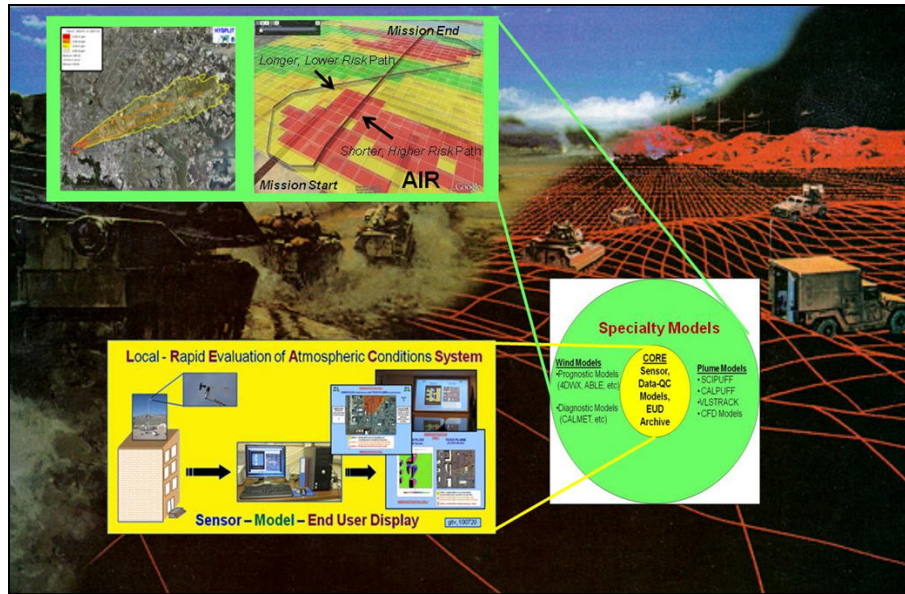
Figure 22. L-REAC® "Core and Second Tier" Design includes the time efficient five module core L-REAC® System running autonomously from the slower, second tier of application model(s).

In Fiscal Year 2011 (FY11), the first attempt at building this second, independently run L-REAC® System was executed. This exercise was part of the 32-bit to 64-bit OS conversion that preceded the Operational L-REAC® System construction. The second computer platform was an Optiplex 755 DELL System with a 64-bit OS. Where the second system construction fell short, was in having only one FSS. Computer security policies prohibited being able to split the data feed between the two systems. Consequently, the dual system design attempt had to be suspended.

With the arrival of the MSS, and the successful integration of this MSS into the Mobile L-REAC® System "PoC," the dual-processor feasibility study resumed. The resulting design is described in the next section.

3.4.1 The L-REAC® "Core and 2nd Tier" System Design

For the "Core and 2nd Tier" Feasibility Study, the "Core" System was the Mobile L-REAC® System with the MSS. This "Core" System was composed of the five-module L-REAC® System (Sensor, QC, Model, EUD, Archive Modules) mounted on a DELL M6500 laptop, using a 64-bit Vista OS. The sensor input was the MSS mounted on the subject building roof, using hard power and wireless data communications.

Aside: During the course of testing, the battery powered MSS option was successfully demonstrated.

The MSS data were ingested and processed by an ARL-developed *Powershell* script. A 1-min sampling rate was recorded in the L-REAC® data file. The system output included

local, DMZ and/or, website endpoint options. The automated system utilized a two step *Startup* routine. The user selected wind model resolution, output endpoints and whether to archive the output imagery, during the second step. Mesonet data were automatically ingested and integrated into the wind model input by an ARL-developed, objective analysis. To the Mobile L-REAC® System, the MSS data were processed as "dedicated data." The Mobile L-REAC® System ran independent of operator intervention, unless a change of model resolution was required, the user requested a re-orientation of the mapped output, or a non-local network interruption occurred.

The L-REAC® "2nd Tier" System was the Operational L-REAC® System. The "2nd Tier" consisted of the five-module L-REAC® System (Sensor, QC, Model, EUD, Archive Modules) mounted on a DELL Precision T7400 workstation, using a 64-bit Vista OS. The sensor input was a FSS mounted on the subject building roof. Hardwire power and wired communications supported the FSS. *Loggernet* was used as the data acquisition software to perpetually ingest the 1-min data samples into an L-REAC® formatted file. The "2nd Tier" system output included local, DMZ, and website endpoints. The automated system design utilized a two step *Startup* routine. The user selected which wind model resolution to run and whether to archive the output images, during the second step. Mesonet data were automatically ingested and an ARL-developed, objective analysis integrated these data for wind model input. The System ran independent of operator intervention, unless a change of model resolution was required, the user requested a reorientation of the mapped output, or a non-local network interruption occurred.

For the dual processor feasibility study, the first test consisted of the following: The "Core" System (Mobile L-REAC® System) ran the 5-m resolution wind model with no plume model, and the "2nd Tier" System (Operational L-REAC® System) ran the 100-m resolution wind model with no plume model. The outputs from both systems were automatically fed to their respective local computers, the common DMZ directory and the common website. Note: The DMZ\lreac directory and website were physically separated from the two Systems; yet, both Systems were authorized to access and write to these locations via a network link.

The time differential required to process the 5- and 100-m resolution models allowed each system to successfully reach their endpoints without any conflicts. The 5-m resolution took between 1 and 2 min to process; the 100-m resolution took between 8 and 10 min.

Due to the many network delays already encountered by the Operational L-REAC® System, a command instructing the computer process to "wait" and "try again" if a file being copied encountered a "busy" status, was used within the automating scripts. No

doubt, this feature was an effective countermeasure for the anticipated, potential dual-processor, file-access conflicts.

Both wind models used the same general AOI. The 5-m resolution, ground (/Earth) image was kept stationary, to help viewers keep their orientation on this detailed image. The 100-m resolution output image was moved around by the operator. While this repositioning could get confusing to the end user, the larger scale overview showed more landmarks, making instant viewing orientation easier. Compass "North" remained in one direction for all images, at the top of the page.

To return the dual-processor design to a single processor design, the "Core" System (Mobile L-REAC® System) operator initiated the *Shutdown* Script and selected the "local" shutdown option. This option made the dual to single processor changeover transparent to the users. In fact, when this option was selected, to the users, the "Core" System-Mobile L-REAC® System would simply no longer provide images. Instead, the "2nd Tier" System (Operational L-REAC® System) would continue updating images without interruption, thus, becoming the new "Core" System from the user's perspective.

In a second test, automated plume overlays were added to the wind field outputs. The results were the same as the first test. EUD output updated when it became available. The dual to single processor shutdown method repeated the above "local" option, and was again transparent to the end users.

An informal third test repeated the four-model, dual processor operations and added the website as a second output receptacle. No system glitches were observed.

With the three tests, here is a sample of the lessons learned:

1. Consistent map orientation between output results is important (see above).

2. When timing between file updates was less than 30 s apart, the user could use the "F5" (instant window update) option on their local PC, to bring in the latest output provided. The longer-to-process results did not necessarily represent the most contemporary information. In these tests, it represented an 8–10 min old atmospheric condition. For strong winds, such results were not always significant. For light winds, the variable directions could be confusing to the inexperienced. On the plus side, the longer-to-process model provided a flow field over a wider AOI.

3. At some point, the L-REAC® System design will allow the end user to change the visual orientation on the output image (i.e., zoom in/out, tilt) from their own terminal. When this feature occurs, the ability to overlay both the higher and lower resolution imagery on a single background needs to be considered. The author stipulates this option as a "consideration," since there will be a point when the decision aid could saturate the end user with "too much information."

4. The dual-processor L-REAC® System design ran up to four models (two wind field models, two plume Models) concurrently on two computer platforms. This study confirms the potential for linking the "core" L-REAC® System with a variety of models.

3.4.2 Future Multi-processor L-REAC® Designs

The ability to run multiple models on more than one computer platform, with a single common endpoint opens up a plethora of opportunities.

First, the multiple applications cited in section 3.3.4, no longer have a processor restriction. Instead, this successful feasibility study confirms the ability to link the "core" L-REAC® System with almost any application (independent of how long it takes to process).

Second, this dual processor design flags the L-REAC® System design as a potential SoS; meaning the L-REAC® System can not only be a contributor to an established SoS, but could be a SoS within its own design.

Finally, during an airborne hazard incident, one of the first questions asked concerns the current winds over and around the incident area. Once the incident is considered "under control," the next critical weather-related question becomes, "What will the atmospheric conditions be 1 to 3, to 6 h from now?" With this study's success, a system can now be designed to also answer this second vital question.

For example: An atmospheric forecast model takes a significant amount of time to run. However, some healthy candidates for this task are the Rapid Update Cycle Model (also known as Rapid Refresh-Weather Research Forecast (WRF) Model), and the Weather Running Estimate-Nowcast (WRE-N) model, which ARL has been developing. Nowcasting is *a method of diagnosing the current weather situation by combining existing forecast guidance with observational data, using various methods of analysis/fusion and assimilation, and then extending this meteorological "picture" forward in time to produce a very short-range forecast or prediction* (Browning, 1982). WRE-N and "Nowcasting" can be considered synonymous. The general target resolution for WRE-N is 1-km grid spacing. The term Nowcasting as associated with WRE-N indicates a frequently-updated and very short range forecast field out 0–3 h (no more than 6) into the future. (Personal Communication, October 04, 2012.) If this forecast model were run on an efficient processor with a "core" L-REAC® System, both customer concerns (current and future atmospheric conditions) could be addressed!

4. A Résumé of Significant L-REAC® Milestones

In four years, the L-REAC® System went from a "viewgraph concept" to an Operational
L-REAC® System. In this fifth year, the L-REAC® System has remained operational and
added a Mobile L-REAC® System "PoC" capability. Several major accomplishments
have been achieved while traversing the L-REAC® System development path. In this
discussion section, a brief résumé showing a sample of the written and verbal System
Endorsements, Collaborations and Technical Achievements is provided.

4.1 L-REAC® System Endorsements

- TRADEMARK: On June 12, 2012, the "L-REAC" trademark was registered with
  the United Stated Patent and Trademark Office (Reg. No. 1459109).

- PATENT: On Apr 20, 2012, a non-provisional patent application was submitted by
  ARL to the United Stated Patent and Trademark Office, for the L-REAC® System
  design.

- NEWS MEDIA ARTICLES: On February 28, 2012, an *L-REAC® System Open
  House* was provided. This event was attended by 18 representatives of various
  government and academic organizations. Three unsolicited news media articles
  featuring the L-REAC® System were generated as a result of this event:

  o *WSMR Newsletter Issue #5*-"Hot Off the T & E Press!" Story, *Army Lab
    Developing Gas 'Plume' Detection System To Protect Soldiers, First
    Responder,* Drew Hamilton, May 2012.

  o *Army News—*Top Army Headlines*, Army Lab Developing Gas 'Plume'
    Detection System To Protect Soldiers, First Responders,* Drew Hamilton,
    March 28, 2012 (http://www.army.mil/)

  o *Missile Ranger—*WSMR Newspaper*, ARL Developing System for Soldiers
    and First Responders,* Drew Hamilton*, March 22, 2012 (Vol. 65, No. 12;
    page 3).

- WRITTEN ENDORSEMENTS:

  o On June 24, 2011, ARL endorsed the L-REAC® System when the ARL
    Invention Evaluation Committee (composed primarily of ARL Fellows)
    approved the L-REAC® System design for Patent submission (see appendix
    A).

  o On May 4, 2010, a written endorsement was received from WSMR Garrison
    Command, COL Christopher Wicker (see appendix B).

- VERBAL ENDORSEMENTS:

  o   In FY12, verbal endorsements were received from WSMR Commanding General—Brigadier General (BG) Ferrari, ARL Safety Manager J. Scott Adams and many users. (Personal Communication, 2012 February 08)

  o   In 2011, Major General (MG) Nikolas Justice, Commanding General of RDECOM at Aberdeen Proving Ground in MD verbally endorsed the L-REAC® System to BG John Regan, Commanding General at WSMR, for implementation at WSMR, NM. (Personal Communication, 2011 April 07) (See appendix C.)

  o   TRAINING: WSMR organizations acknowledged the L-REAC® System value by requesting and sending their workforce to ARL-sponsored training sessions. For one agency, this mandatory training required overtime pay. ARL conducted 14 training sessions between 2011 and 2012; 44 people attended the *User* and *Operator Training* sessions in 2011, and 17 people attended the *Refresher Training* in 2012. Repeat *Refresher Training* sessions for those unable to attend the first, were requested.

4.2   L-REAC® Collaborations

Note: The first three collaborations were prompted by the *L-REAC® System Open House* (February 28, 2012).

- FORT BLISS, TX: ARL collaborated with Fort Bliss–DPTMS (chemical, biological, radiation, nuclear effects [CBRNE]) Donald Patterson in the JPM Guardian, System of Systems Feasibility Study.

- ARL/CES CRADA: ARL collaborated with Coastal Environmental Systems, Inc (Vice President Product Development–Tim Parker, Marketing Development Director–Kathy Jones, Product Manager–Jennifer Hemmingway), which led to the Mobile Sensor Suite Feasibility Study.

- WSMR/IMD: ARL collaborated with WSMR IMD, WSDM Webmaster Joseph Pratt, which led to the WSDM L-REAC® System website development. This website is now an operational feature of the L-REAC® System.

- EMERGENCY OPERATIONS COMMUNITY: The L-REAC® System began collaborating with the "real world" WSMR Emergency Response community in April 2011, during the "Abrams Fire" incident at WSMR, NM. The 24/7 operational status has continued through the time of this writing. L-REAC® provided wind/airborne hazard output for over 10 Incidents/Forces Protection Exercises.

- TRAINING [alphabetically listed]: During the FY11–12 L-REAC® Training Sessions, collaboration was conducted with ARL–Associate Director for Laboratory Operations (ADLO), ARL–Survivability, Lethality and Analysis Directorate (SLAD), ARL–Computational Information Science Directorate (CISD)\Atmospheric Dynamics and Atmospheric Modeling Application Branches, Army Test and Evaluation Command (ATEC)\HELSTF, WSMR–DES\Fire Department, WSMR–DPTMS\EOC, WSMR–DPTMS\Installation Operations Center (IOC), WSMR–IMD, WSMR–PAIO and White Sands Range (WSR) Operations Directorate–Operations Control Division, Flight-Safety-Branch, Forecast-section (CFF). These collaborations not only generated informed professional/voluntary emergency response system Users and Operators, but the detailed user-feedback which was published in *Volume 4* (Vaucher et al., 2011).

4.3 L-REAC® Technical Milestones

- Four physical L-REAC® Systems were constructed, with five designs tested:

  o The "Core and Second Tier" Design: Mobile–"Proof of Concept" and Operational L-REAC® Systems (2012).

  o Mobile L-REAC® System "Proof of Concept" (2012).

  o Operational L-REAC® System (2011).

  o L-REAC® System Prototype (2010).

  o L-REAC® System "Proof of Concept" (2009).

- Four feasibility studies were successfully completed in FY12. These studies:

  o Expanded local and DMZ output options, to include a website.

  o Integrated the L-REAC® output into a SoS,

  o Augmented the dedicated sensor to include FSS and MSS.

  o Simulated a multi-processor L-REAC® System design.

5. Summary and Final Comments

This report is the fifth and possibly final L-REAC® System development report. Due to budget cuts, the ARL management has decided that any further L-REAC® System development will need a sponsor outside of ARL mission funding. The L-REAC® System has consistently shown itself to be a valuable, user-friendly asset to the emergency response community. This same emergency response community recently underwent a re-organization, suspending any immediate integration of the L-REAC® System technology. Instead, a local safety-operations group within ARL has agreed to continue the L-REAC® System operational function. At the time of this writing, the transfer of the L-REAC® System operational function was in progress.

The long term vision of the L-REAC® System is to bring this technology to the Army Soldier. While the continued development of current L-REAC® technology is pending funding, it is the hope of the author that enough of the system details have been documented, so that when the need and funding come together, the next development effort can bring this technology to its intended goal. That is, the L-REAC® decision aid will continue to make a difference in the mission of saving civilian and Soldier lives.

6. References

ALOHA User's Manual, The CAMEO Software System, EPA/NOAA, February 2007.

Browning, K.A. *Nowcasting*; Academic Press: New York, 1982, p 256.

Consequences Assessment Tool Set (CATS), http://idn.ceos.org/KeywordSearch/Metadata.do?Portal=GCMD_Services&KeywordPath=ServiceParameters%7CHAZARDS+MANAGEMENT&EntryId=CATS_Model&MetadataView=Full&MetadataType=1&lbnode=mdlb1 (accessed 2012 October 1).

Drew Hamilton, *ARL Developing System for Soldiers and First Responders, Missile Ranger –* WSMR Newspaper, Mar 22, 2012 (Vol. 65, No. 12; page 3).

Drew Hamilton, *Army Lab Developing Gas 'Plume' Detection System To Protect Soldiers, First Responders, Army News–*Top Army Headlines*, Mar 28, 2012 (*http://www.army.mil/*)*.

Drew Hamilton, *Army Lab Developing Gas 'Plume' Detection System To Protect Soldiers, First Responder, WSMR Newsletter Issue #5–*"Hot Off the T & E Press!" story, May 2012.

Grid Analysis and Display System (GrADS), http://grads.iges.org/grads/grads.html (accessed September 2010).

Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD), Mission, http://www.jpeocbd.osd.mil/packs/Default2.aspx?pg=150 (accessed 2012 October 1).

HazMat/First Responder WEATHERPAK®, 2011: Costal Environmental Systems, Inc.; *Brochures:* http://www.coastalenvironmental.com/setions/er_weatherpak.shtml (accessed October 2009 and 2011).

Personal Communication (e-mail): *Briefing to MG Justice today (UNCLASSIFIED)*, Dr. Donald Hoock, 2011 April 7.

Personal Communication (verbal): *L-REAC® Open House*, CES-Jennifer Hemmingway, 2012 February 28.

Personal Communication (e-mail): *NOTES, M-LRx: BG Ferrari, 120207-LRx Bfg/Demonstration (UNCLASSIFIED),* Attachment: *120207_BG_Ferrari_LRx_Bfg_Demo.doc*, February 8, 2012.

Personal Communication: (e-mail from Mr. Robert Dumais, Jr. to Gail Vaucher), 2012 October 4.

Personal Communication: (e-mail between Jennifer Hemmingway and Gail Vaucher), 2012 December.

Snyder, W.; Lawson, Jr., R. *Wind-Tunnel Measurements of Flow Fields in the Vicinity of Buildings*, 8th Conference on Applied Air Pollution Meteorology with A&WMA, Nashville, TN, AMS, Boston, January 1994, pp 244–2504.
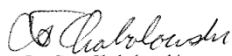
Vaucher, G. T. *White Sands Missile Range Urban Study: Flow and Stability Around a Single Building, Part 1: Background and Overview*; ARL-TR-3851; U.S. Army Research Laboratory: White Sands Missile Range, NM, July 2006.

Vaucher, G. T. *Urban-Small Building Complex Environment: Comparing Stable Patterns from Two Similar Urban Field Studies, Volume AS-1*; ARL-TR-4456; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2007.

Vaucher, G. T. *Urban-Small Building Complex Environment: W07US Stability Analysis and Inter-Study Comparison, Volume AS-2*; ARL-TR-4452; U.S. Army Research Laboratory: White Sands Missile Range, NM, May 2008.

Vaucher, G. T.; Brice, R.; D'Arcy, S.; Bustillos, M.; Cionco, R. *White Sands Missile Range 2007 Urban Study: Data Processing - Volume DP-1 (Sonic Calibration)*; ARL-TR-4439; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2008a.

Vaucher, G. T.; Brice, R.; D'Arcy, S.; Bustillos, M.; Cionco, R. *White Sands Missile Range 2007 Urban Study: Data Processing - Volume DP-2 (Main Dataset)*; ARL-TR-4440; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2008b.

Vaucher, G.T.; Bustillos, M. *White Sands Missile Range 2007 Urban Study: Data Processing - Volume DP-3 (Airflow Qualitative Assessment)*; ARL-TR-4441; U.S. Army Research Laboratory: White Sands Missile Range, NM, May 2008c.

Vaucher, G.T. *White Sands Missile Range 2007 Urban Study (W07US): Data Analysis, Volume DA-1 (Analysis of Disaster Response Drills and Concurrent Atmospheric Data)*; ARL-TR-5706; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2011.

Vaucher, G.T.; Luces, A.; O'Brien, S.; Brice, R.; Bustillos, M.; D'Arcy, S. *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC) System, Design and Development, Volume 1 ("Proof of Concept")*; ARL-TR-4958; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2009.

Vaucher, G.T.; Luces, A.; O'Brien, S.; Brice, R. *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC) System, Design and Development, Volume 2 ("Prototype")*; ARL-TR-5332; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2010.

Vaucher, G.T.; Brice, R.; Luces, Saba A.; O'Brien, S. *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC™) System, Design and Development, Volume 3 ("Operational L-REAC™")*; ARL-TR-5727; U.S. Army Research Laboratory: White Sands Missile Range, NM, September 2011.

Vaucher, G. *Local-Rapid Evaluation of Atmospheric Conditions (L-REAC) System, Volume 4 (System Evaluation)*; ARL-TR-5848; U.S. Army Research Laboratory: White Sands Missile Range, NM, December 2011.

Wang, Y.; Williamson, C.; Garvey, D.; Chang, S.; Cogan, J. Application of a Multigrid Method to a Mass-consistent Diagnostic Wind Model. *J. Appl. Meteorol.* **2005**, 44, 1078–1089.

Appendix A. Written Endorsement by ARL

On June 24, 2011, ARL endorsed the L-REAC® System when the ARL Invention Evaluation Committee (composed primarily of ARL Fellows) approved the L-REAC® System design for Patent submission. The two-page letter of endorsement follows:

DEPARTMENT OF THE ARMY
US ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND
ARMY RESEARCH LABORATORY
2800 POWDER MILL ROAD
ADELPHI MD 20783-1197

RDRL-DP

JUN 29 2011

MEMORANDUM FOR: Gail T. Vaucher (RDRL-CIE-D), Robert O. Brice (RDRL-CIE-D), Saba A. Luces (RDRL-CIE-D), and Sean G. O'Brien (RDRL-CIE-D)

SUBJECT: Invention Evaluation Committee Evaluation of Invention Disclosure entitled, "Local-Rapid Evaluation of Atmospheric Conditions [L-REAC] System" Docket No.: ARL 11-28

1. Official action has been taken with respect to the above-identified subject invention.

2. Congratulations, the Invention Evaluation Committee (IEC) recently re-evaluated your invention on **6/24/2011** and determined that there is sufficient government interest for pursuing patent protection. This disclosure is a P0 rating and supersedes any previous rate/score.

3. The IEC consists of members having technically diverse backgrounds from each of ARL's organizational units. Advisors to the IEC come from the Office of Chief Counsel, Intellectual Property (IP) Law Branch, and technology transfer office.

4. For your information, here is a short description of the IEC's rating criteria.

Sufficient Government Interest - The IEC determines if ARL has sufficient interest in the invention for pursuing patent protection. There are various factors the IEC considers for determining whether there is sufficient Government interest. At this step in the process the invention is reviewed for (1) Government (Military) Use / Defensive IP Needs (e.g., government wide procurement cost savings); (2) Commercial Licensing Potential and (3) technical significance (e.g., importance of the invention to the art). If an invention's performance and value to the Army has been demonstrated it is probable that ARL will have sufficient interest in pursuing patenting. Information on dual use applications of an invention can also influence the IEC's selection of the invention for patenting due to its commercial licensing potential.

Insufficient Government Interest – The IEC may determine that there is insufficient Government interest in pursuing patent protection. When the Government has insufficient interest in pursuing patent protection, and if the invention is cleared for public release, the inventors may be authorized to pursue patent protection privately, if they so choose. In such a case, the Government retains a Government purpose license but the inventor would be the owner of the patent to exploit commercially.

Assigning Ratings - An invention disclosure may be given one of the following ratings: (P0) sufficient government interest – pursue patenting; (P1) sufficient government interest – pursue patenting but only if resources allow; (P2) insufficient government interest; (P3) inactive file; (P4) insufficient information.

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5. If there are no outstanding matters that need to be addressed, the next step will be for the IP Law Branch to have a patent application prepared. You will be asked to review the application before it is filed with the U.S. Patent & Trademark Office.

Dr. Cary Chabalowski
Chairperson (A)
Invention Evaluation Committee

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Appendix B. Written Endorsement by WSMR Garrison Commander

A written endorsement was received by ARL, from WSMR Garrison Command, COL Christopher Wicker on May 4, 2010. The two-page letter of endorsement follows:

DEPARTMENT OF THE ARMY
U.S. ARMY GARRISON WHITE SANDS
100 Headquarters Avenue
WHITE SANDS MISSILE RANGE, NEW MEXICO 88002-5000

REPLY TO
ATTENTION OF

IMWE-WSM-ZA

MEMORANDUM FOR: US Army Research Laboratory, (RDRL-D/Mr. John M. Miller), 2800 Powder Mill Road, Adelphi, MD 20783

SUBJECT: Endorsement Memorandum for the Army Research Laboratory (ARL) "Local Rapid Evaluation of Atmospheric Conditions (L-REAC)" Project

1. The White Sands Missile Range (WSMR) Garrison Command, Installation Management Command (IMCOM) is pleased to endorse the ARL proposal to establish a "Local Rapid Evaluation of Atmospheric Conditions (L-REAC)" system for 24/7 monitoring of winds and airborne agent threats across the WSMR main post area. We have been coordinating with Ms Gail Vaucher, L-REAC Project Leader (commercial 575 678-3237) and Dr. Donald Hoock, Chief, Atmospheric Dynamics Branch (commercial 575 678-5430) of the ARL Computational and Information Sciences Directorate, Battlefield Environment Division (CISD/BED), a WSMR tenant organization.

2. The L-REAC capability will enhance the life, health and safety goals of the installation. It will provide our command staff and our emergency services leadership immediate access to real time information on current wind flow around the buildings in the main post area. In the event of an accidental or intentional release of hazardous materials into the atmosphere, the L-REAC displays will help us to plan and make decisions on evacuation, shelter in place and routing of first response emergency units to keep them out of the hazard area. The capability to zoom in to the affected area and to execute fast running hazard footprint models will help us to track the plume and its arrival times downwind as well as to assess when the danger has passed.

3. We plan to support this unique new capability by making this system a part of our installation protection plan for access at our Information Operations Center. An early prototype that was successfully used in past force protection exercises was confined to predicting the flow around a small complex of ARL buildings on post using a single meteorological sensor. The WSMR ATEC Meteorological Branch has agreed to provide data from several meteorological monitoring towers across WSMR as inputs to the L-REAC system. We intend to use L-REAC as a showcase and evaluation test bed for its potential deployment to other IMCOM installations and potentially for use at forward operating bases.

4. The WSMR IMCOM Garrison points of contact are Charlie Benavidez, DPTMS, Plans & Operations Division, 575-678-3803; charlie.benavidez@us.army.mil. Ed Taitano, DPTMS, Plans Officer, 575-678-3674; edward.taitano@us.army.mil.

C. J. WICKER
COL, LG
Commanding

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Appendix C. Verbal Endorsement by MG Justice

MG Justice verbally endorsed the L-REAC® System and suggested its use not only for the WSMR Garrison, but also for WSMR tests and exercises. The e-mail documenting this verbal exchange between the two Battlefield Environment Division (BED) Branch Chiefs and MG Justice follows. Only the L-REAC® relevant information is displayed. POC: Dr. Donald Hoock–Chief, Atmospheric Dynamics Branch (Personal Communication, 2011 April 07).

From: Hoock, Don (Civ, ARL/CISD)
Sent: Thursday, April 07, 2011 4:43 PM
To: RDRL-CIE-D
Subject: Briefing to MG Justice today (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

Today Dave Knapp and I had 15 minutes of MG Justice's time to brief him while here at WSMR.

Actually we got 12 minutes and he took an additional 15 minutes to express his thoughts.

Here is a summary of the highlights of the briefing. ....

Don Hoock and David Knapp of the ARL CISD Battlefield Environment Division briefed MG Justice, Commander RDECOM and BG Regan, Commander WSMR in bldg... WSMR on Thursday 7 April 2011 on the BED R&D program and on...

MG Justice endorsed the BED L-REAC 24/7 installation wind flow and hazard warning system and suggested its use not only for the WSMR Garrison, but also for upcoming tests or exercises at WSMR. Follow up action: The WSMR garrison commander COL Wicker is aware of and has endorsed this system. Get on BG Regan's calendar to brief him on the L-REAC capabilities and the costs associated with its implementation.
....

Don Hoock
Chief, Atmospheric Dynamics Branch

US Army Research Laboratory
Computational and Information Sciences Directorate
Battlefield Environment Division
RDRL-CIE-D
White Sands Missile Range, NM 88002-5501
Phone: (575) 678-5430; DSN: 258-5430
email: Donald.Hoock@us.army.mil

Classification: UNCLASSIFIED
Caveats: NONE

List of Symbols, Abbreviations, and Acronyms

24/7   24-h a day/7-days a week

1P   One Plot EUD image

2P   Two Plot EUD image

3DWF   Three-Dimensional Wind Field

(μUAV)   micro-unmanned aerial vehicle

ADLO   Associate Director for Laboratory Operations

AGL   above ground level

ALOHA   Aerial Locations of Hazardous Atmospheres

AOI   area of interest

ARL   U.S. Army Research Laboratory

ATEC   Army Test and Evaluation Command

BED   Battlefield Environment Division

BG   Brigadier General

CATS6   Consequences Assessment Tool Set-Version 6

CBRN   chemical, biological, radiological, and nuclear

CBRNE   chemical, biological, radiation, nuclear effects

CES   Coastal Environmental Systems, Inc.

CFF   Control Division, Flight-Safety-Branch, Forecast-section

CISD   Computational Information Science Directorate

CONUS   Continental United States

COTS   commercial-off-the-shelf

CRADA   Cooperative Research and Development Agreement

DES   Directorate of Emergency Services

DMZ   Demilitarized Zone

DoD	Department of Defense
DPTMS	Directorate of Plans, Training, Mobilization and Security
DTED	Digital Terrain Elevation Data
EMC	Emergency Management Coordinator
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
EPA/NOAA	Environmental Protection Agency/National Oceanic and Atmospheric Administration
EUD	End User Display
FSS	Fixed Sensor Suite
FY10	Fiscal Year 2010
FY11	Fiscal Year 2011
FY12	Fiscal Year 2012
GIS	Geographical Information System
GPS	Global Positioning System
GrADS	Grid Analysis And Display System
GUI	graphical user interface
HAZMAT	hazardous material
HDTV	high definition television
HPAC	Hazard Prediction and Assessment Capability
HTML	Hyper Text Markup Language
IMD	Information Management Division
IMS	Installation Management System
IOC	Installation Operations Center
JPEO-CBD	Joint Program Executive Office for Chemical and Biological Defense
JPM	Joint Project Manager
kml	keyhole markup language

L-REAC®	Local-Rapid Evaluation of Atmospheric Conditions
LT	local time
MG	Major General
MSS	Mobile Sensor Suite
MTR	Multiple Threat Response
NASA	National Aeronautics and Space Administration
NED	National Elevation Dataset
NOAA	National Oceanic and Atmospheric Administration
OS	operating system
P&O	Plans and Operations
PAIO	Plans, Analysis and Integration Office
PoC	Proof of Concept
QC	Quality Control
RH	Relative Humidity
s	second
SAIC	Science Applications International Corporation
SAMS	Surface Automated Meteorological System
SIP	Shelter-in-Place
SLAD	Survivability, Lethality and Analysis Directorate
SoS	System of Systems
UPS	uninterruptable power supply
W03US	*White Sands Missile Range 2003 Urban Study*
W05US	*White Sands Missile Range 2005 Urban Study*
W07US	*White Sands Missile Range 2007 Urban Study*
WRF	Weather Research Forecast
WRE-N	Weather Running Estimate-Nowcast

WSDM	White Sands Data Management
WSMR	White Sands Missile Range
WSR	White Sands Range

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